

Assessment of long-term temporal changes in the macrobenthic communities south of Peel Island, Moreton Bay, Queensland

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ABSTRACT

A grab sampling survey of 15 sites in a relatively small geographic area to the south of Peel Island, Moreton Bay, Queensland, was undertaken in February 2005. This broader area is already known as a biodiversity hot-spot within the Bay. The sampling was designed to replicate a longer-term survey undertaken 35 years earlier between March 1970 and December 1971. The new study was intended to assess changes to species composition of those earlier communities after so many years, and provide a yardstick on the present ecological health of the system. The sediments, and hydrographic features such as depth and currents appear not to have changed significantly. There have however been some minor changes in site groupings based on species presence, and a marked change in the species characterising the site groupings. In particular, in 2005 there was an absence of benthic tunicates that had been an important component at some sites in the earlier survey; and secondly, there has been the development of significant *Trichomya* mussel aggregations that had not been noted from this area in the past. An analysis of community trophic structure found essentially the same site classification as the simple species x sites analysis, and as found in other studies, deposit feeders predominate in the muddiest site-groups. Overall, the species richness was very high (564 species), and this was greater than the 394 species found earlier. It is believed the earlier survey had under-estimated the number of species present. There is every indication that the present communities in this area are healthy and resilient. □ *ecology, marine, macrobenthos, Moreton Bay, communities, sediments, trophic structure, biodiversity.*

Around the world, human impacts on estuarine and coastal environments have been dramatic since the advent of the industrial revolution (Lotze *et al.* 2006), but arguably have accelerated significantly over the last 50 years. This has been a time of massive human population explosion with concomitant encroachment and destruction of coastal environments, pollution

from an increasingly complex and unpredictable arsenal of chemicals, and wholesale marine resource over-exploitation. Moreton Bay (Fig. 1), is a sheltered, coastal embayment, with one of Australia's largest cities on its foreshores. Over the last 30 years, the Brisbane–Gold Coast corridor has become one of the fastest growing human population centres in the developed

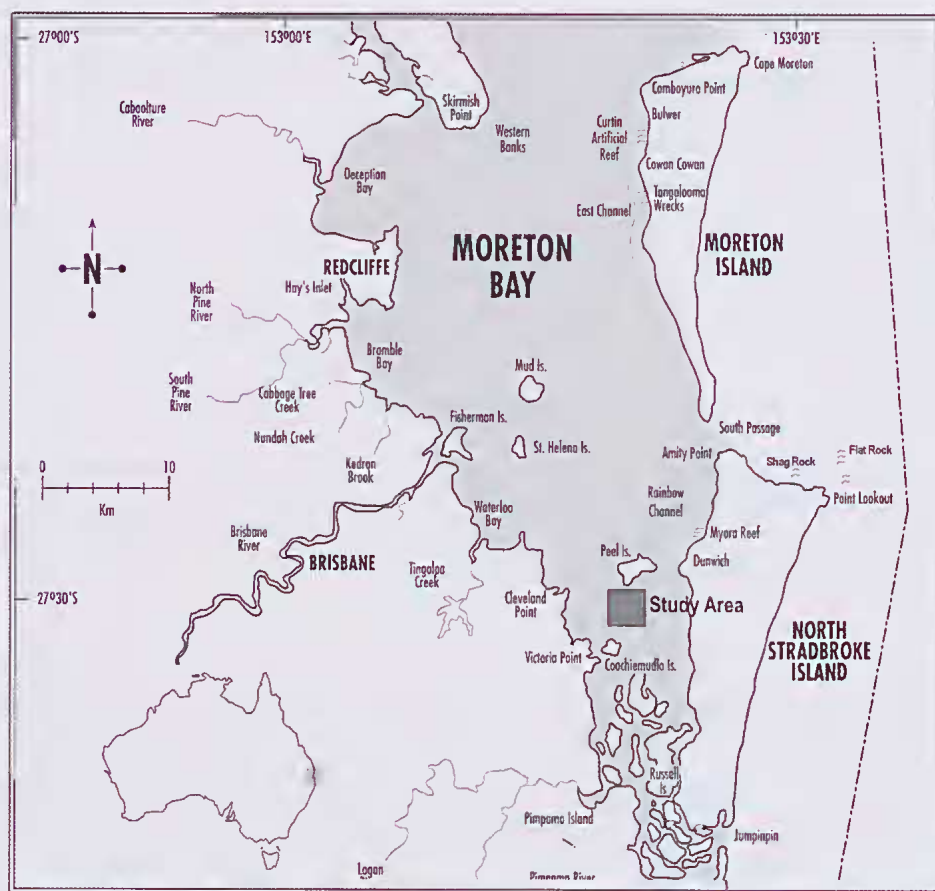


FIG. 1. Map of Moreton Bay showing the sampling area (dark gray square) just to the south of Peel Island, in the southern part of the Bay.

world, and thus has a major impact potential on the Moreton Bay region.

Moreton Bay is protected from the South Pacific Ocean by the large sand islands of North and South Stradbroke, Moreton and Bribie. To the north and east it is primarily oceanic while to the south and west the Bay becomes a complex estuarine system, with numerous islands and muddy banks in its southern portion. Interestingly it lies at the subtropical/temperate biogeographic transition zone (see Davie & Hooper 1998), and has an extraordinary mix of southern Australian endemic species and widespread tropical Indo-West Pacific and Great Barrier Reef species.

Our understanding of Moreton Bay's faunal composition and ecological processes have grown considerably over the last 30–40 years (see review by Skilleter 1998). Extensive studies

have been made of the soft bottom macrobenthos of Moreton Bay (e.g. Raphael 1974; Stephenson *et al.* 1970, 1974, 1976, 1977, 1978; Poiner 1979a, b; Stephenson & Cook 1977, 1979; Stephenson 1980a, b, c; Stephenson & Sadacharan 1983; Lörz & Bamber 2010, this volume). Trawl studies were conducted by Jones (1973), Stephenson & Dredge (1976), Quinn (1979, 1980), Burgess (1980), Stephenson & Burgess (1980), and Stephenson *et al.* (1982a, b). Dredged macrobenthos near the mouth of the Brisbane River was reported on by Hailstone (1972, 1976), Boesch (1975) and Park (1979). Campbell *et al.* (1974) studied nine estuaries in southeastern Queensland, most of which feed into Moreton Bay, and Campbell *et al.* (1977), Stephenson & Campbell (1977) and Davie (1986), reported on the sublittoral macrobenthic fauna of Serpentine and Jackson's Creeks. Young & Wadley (1979) also examined the distribution of shallow water epibenthic

macrofauna in the Bay. Most recently Stevens & Connolly (2005) mapped and classified macrobenthic habitat types by using a compact video array at 78 sites spaced 5 km apart. They recognised nine habitats, with only one being on hard substrate. These included previously unreported deep-water algal and soft-coral reefs, and new areas of seagrasses. Broader ecological work on understanding nutrient cycling and the impact of sewage on the western Bay was also undertaken during the 1990s, and this has also contributed significantly to our understanding of the ecological dynamics of the Bay and the Brisbane River (Dennison & Abal 1999).

Conservation of biodiversity is a major priority for the continued healthy functioning of communities, but marine biodiversity issues have not received the attention currently given to terrestrial systems, perhaps because they are less easily studied, impacts are less conspicuous, and taxonomic difficulties are immense. Davie & Hooper (1998) examined the species richness and distributional patterns of the fauna inside Moreton Bay and identified two major biodiverse regions — an inshore estuarine-dominated region, and an eastern marine-dominated region. This latter region, including the northern end of Stradbroke Island, and Peel, Bird and Goat Islands had the highest species richness in the

whole Bay, most likely because of its well developed coral reefs and a mix of consolidated hard and muddy-sand bottoms.

The study reported here was undertaken during the Thirteenth International Marine Biological Workshop, held in Moreton Bay. The intention was to repeat the earlier survey of Stephenson *et al.* (1974) of 15 sites in a relatively small geographic area to the south of Peel Island. As already noted this region has been identified as one of the biodiversity hot-spots in the bay. The work of Stephenson *et al.* (1974) involved 8 sampling times over three-monthly intervals for two years from March 1970 to December 1971, thus also providing them with patterns of seasonal change. While the new sampling was a once-off snapshot of the area 35 years later, we hoped that this would provide some interesting insights into the state and composition of these communities after so many years, and provide an indication of the system's current ecological health.

MATERIALS AND METHODS

POSITIONS AND DEPTHS OF SITES

The present work was carried out towards the northern end of the southern half of Moreton Bay immediately south of Peel Island.

Table 1. Station details for grab samples taken south of Peel Island, southern Moreton Bay, February 2005. Salinities were not taken consistently, but were around 28‰ at all sites during the period of sampling.

Station No.	Latitude	Longitude	Depth	Date
1	27°31.25'	153°22.00'	6.5 m	17.02.2005
2	27°31.25'	153°21.85'	6.6 m	17.02.2005
3	27°31.25'	153°21.65'	6.4 m	18.02.2005
4	27°31.53'	153°21.44'	5.9 m	20.02.2005
5	27°31.53'	153°21.70'	6.5 m	20.02.2005
6	27°31.55'	153°20.80'	8.5 m	18.02.2005
7	27°31.48'	153°20.72'	9.0 m	18.02.2005
8	27°31.48'	153°20.48'	9.2 m	18.02.2005
9	27°31.61'	153°20.38'	7.6 m	20.02.2005
10	27°31.68'	153°20.54'	8.4 m	18.02.2005
11	27°32.39'	153°20.80'	4.2 m	17.02.2005
12	27°32.20'	153°20.75'	3.9 m	20.02.2005
13	27°31.98'	153°20.62'	7.0 m	20.02.2005
14	27°32.29'	153°20.42'	5.1 m	20.02.2005
15	27°32.61'	153°20.42'	4.4 m	17.02.2005

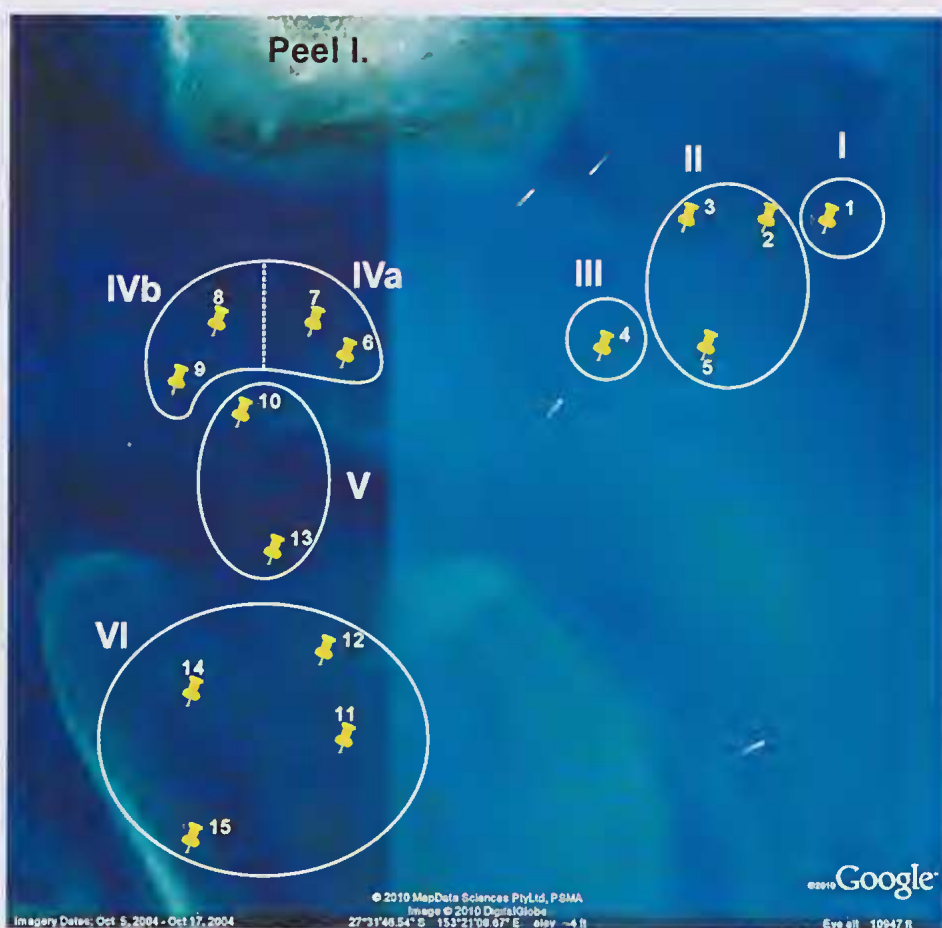


FIG. 2. Positions and groupings of the sample sites. Specific coordinates are given in Table 1. The explanation for the site-groupings is explained later in the text.

In a landmark dredge study of the macrobenthos of Moreton Bay, Stephenson *et al.* (1970) established this area as having a rich fauna and a small scale patterning of 'communities'. Their work was subsequently followed-up (Stephenson *et al.* 1974), by an intensive grab-sampling study where fifteen stations were sampled in quintuplicate in each of four seasons for two years (from March 1970 to December 1971). The objective of that work was to investigate a suspected complex benthic biota and to attempt to resolve the complexity into a number of spatial and temporal patterns.

Stephenson *et al.* (1974) sampled five sites in each of three areas to reflect contrasting bottom topographies as revealed in published charts available at the time. While they stated in their paper that the site 'positions have been established by horizontal sextant angles of conspicu-

ous fixed points (data filed in archives of Queensland Museum)', we were unable to locate these data in the Queensland Museum, and instead we interpolated the positions using modern mapping software. The positions of the sites for the 2005 sampling are shown in Fig. 2, and the coordinates are given in Table 1. All sites are enclosed within an area of approx. 3 km². Topographic grouping of sites can be summarised as: 'Goat Island slope' (Sites 1–5); 'North-west gutter' (6–10, 13); 'Southern shallows' (11, 12, 14, 15).

Depths of sampling sites ranged from 3.9–9.2 m at the time of sampling (Table 1), reflecting the depths of 2.4–9.3 m given by Stephenson *et al.* (1974). The apparent slightly greater depth at our shallowest sites may be due to factors such as sampling on a higher tide, or differences in specific site location. Overall there appears to

have been no significant movement of banks, or changes in depths, since the sampling at the beginning of the 1970s.

SAMPLING

Quintuplicate samples were collected at each site using a long-arm van Veen grab with a surface sampling area of 0.1 m² (total sampling area = 0.5 m²/site). Faunal samples were washed on board the vessel through a series of graded sieves down to a 0.5 mm mesh, and the contents of each sieve were washed into a large plastic bag and preserved with 4% formalin. In the laboratory the faunal samples were again washed, transferred to 70% ethanol, and stained with Rose Bengal. The fauna was removed from the samples using elutriation, and by hand-picking using forceps under a dissecting microscope. Despite the 0.5 mm fraction being retained, sorting was only undertaken to the 1 mm stage due to time and labour constraints, and because this was sufficient to provide a valid comparison with the original sampling regime of Stephenson *et al.* (1974). The initial sort was to major taxa, followed by more precisely splitting group by group into recognisable OTUs (operational taxonomic units). Identification was undertaken to the lowest taxonomic rank possible depending on available expertise. Unfortunately it was logistically impossible to check identifications against the original reference collection of Stephenson *et al.* (1974), so there is not necessarily concordance in nomenclature between that and the present study. In addition, there have been significant changes in nomenclature in many groups over the last 35 years, and we have not tried to track these when comparing the two data sets. It is nevertheless interesting, as will be further discussed, that there has been a very clear and real shift in characterising species at many sites.

Individual species counts from the replicate samples were lumped for further analyses in order to minimise the effects of micro-patchiness between samples, and to get the best possible reflection of the community composition at each site. All species were also assessed for their trophic status, and assigned to one of five categories, viz., 1, Suspension feeder; 2, Deposit feeder; 3, Grazer; 4, Predator/Scavenger; or 5, Parasite. The trophic structure of each site was

then also assessed against sediment structure to see if any obvious patterns emerged in community structure.

All samples are deposited in the collections of the Queensland Museum, Brisbane.

SEDIMENTS

At each site a separate grab sample was taken, and subsequently a 200–250 gm subsample was taken in the lab for sediment particle size analysis. Sediments were washed through a series of graded sieves (2.0, 1.0, 0.5, 0.250, 0.125, 0.063 mm). Similar sieves were used by Stephenson *et al.* (1974) (viz. 1.98, 1.02, 0.53, 0.211, 0.15, 0.099 mm) to grade the series of retained fractions as gravel, very coarse sand, coarse sand, medium sand, fine sand and very fine sand respectively, and the non-retained fraction as mud. The retained portion of each sieve was air dried, baked in a microwave oven to remove all moisture, and weighed; the remaining sediment was washed into a coffee-filter paper, similarly dried and weighed (minus the weight of the filter paper). Weights were converted to percentages so that the composition of each sample could be compared. Results are presented in Table 2. The general results are not dissimilar to those of Stephenson *et al.* (1974). Figure 7 clearly shows the significant differences in sediment composition between the derived site-groups. These are discussed further in relation to faunal trophic patterns later in the paper. Stephenson *et al.* (1974) considered 'mud' to be the portion not retained by their finest sieve (99 µm) — in the present study our finest sieve was 63 µm and thus the results are not directly comparable. Their 'mud' component could be expected to be relatively higher than our result, as less was retained by their finest sieve. This is highlighted by Site-Group II (Sites 2–5) where they found a >50% mud component (< 99 µm), whereas our result was 34% for <63 µm, but 87% at 63 µm. Thus the sites we sampled were similarly very muddy, but not directly comparable with the terminology of Stephenson *et al.* (1974), at least at the very finest particle size.

Stephenson *et al.* (1974) found some significant changes in sediment structure at a number of sites between sampling times from March 1970 and December 1971. In particular important changes were: less mud at Stn 5; less fine sand

Table 2. Sediment composition at each site as retained by graded sieves, and particle size expressed as a percentage of each sample.

Stn No./ Grain Size	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2 mm	0.8	2.5	4.6	0.9	0.7	9.3	10.2	20.4	16.7	8.6	4.3	7.1	4.2	9.0	12.7
1 mm	0.7	1.3	2.3	0.5	0.6	9.7	0.7	8.3	7.9	6.7	2.9	2.0	3.2	8.1	6.4
500 µm	0.7	1.0	1.7	0.5	0.6	16.2	15.2	10.0	11.5	5.4	2.8	2.2	2.4	6.8	8.4
250 µm	18.5	3.8	1.4	0.7	0.7	24.6	26.3	14.6	29.3	11.9	34.8	38.7	5.7	36.3	41.9
125 µm	30.6	6.7	5.2	33.8	6.8	23.6	21.0	13.8	24.1	55.3	48.0	42.8	55.0	33.5	21.0
63 µm	18.9	50.2	50.8	47.0	56.2	4.2	6.1	5.5	2.2	7.7	2.9	2.9	20.7	3.0	5.6
<63 µm	29.9	34.5	34.0	16.5	34.4	12.6	20.5	27.4	8.2	4.4	4.3	4.3	8.8	3.4	4.0

and more mud at Stn 12; more very coarse and medium sand and less mud at Stns 13 and 14; and less coarse, medium and fine sand and more very fine sand and mud at Stn 15 (11–15). Most of these changes over time occurred in the group of 'Southern Shallows' sites. The most aberrant sites in terms of sediments were 1, 4 and 13 (very similar to the present results), and they were able to further subdivide sites on the basis of percentages of coarse sand, with sites 6, 7 & 8 having > 60%, and 9, 10 & 13 < 60% (again very close to the site-groupings based on sediment obtained in the present work).

WATER MOVEMENTS

Tidal currents flow south around Peel Island from the north-east and north-west, leaving a 'slacker-water' area which includes sites 1–5 (see Patterson & Witt 1992: fig. 11). Conversely, the more westerly area that includes sites 6–13 has strong tidal currents that may reach 2–3 knots (at the surface at least), during spring tides. The more easterly sites (1–5) are also more influenced by clean oceanic water flowing from the north-east through the Rainbow Passage (Stephenson *et al.* 1974). The other more westerly and southerly sites (6–15) are more influenced by tidal flows from the western and central portions of the Bay and are thus under greater terrestrial influence, particularly dilution by flood waters (consequently higher turbidity and greater possibilities of pollution), and greater temperature variation. The main influence of floods in the area is from the Logan-Albert Rivers which discharge from the south. Overall, the whole study area is generally relatively protected from the open Bay to the north, and waves are due to local winds. There is typically

a seasonal pattern with winds from north to east predominating between December and April, and from south to southwest between May and August (Newell 1971). The longest wind-fetches in the sampling area are in an arc from south to southeast, and wave-action is severest when these winds blow against a flooding tide from the north. This, and the shallow depths, makes the most southerly sites 11, 12, 14 and 15, the most wave-affected.

TROPHIC STRUCTURE

The relationship between feeding type and sediment characteristics has been well documented and explored for many years (e.g. see Gray, 1974; Rhoads 1974; Lopez & Levinton 1987). The classification of benthic invertebrates into infaunal trophic feeding groups can be quite complex, and has even been developed into a numerical index for ecological mapping (Word 1980).

We have adopted a basic system consisting of five categories: 1, suspension feeder; 2, deposit feeder; 3, grazer; 4, predator/scavenger; 5, parasite. This is similar to that used in some recent Australian studies that have explored the trophic relationships of both tropical (Long & Poiner 1994), and temperate macrobenthic infaunal communities (Poore & Rainer 1974; Wilson *et al.* 1993). A 'parasite' category was included initially because of the high incidence of a bopyrid isopod in the gill chamber of a common porcellanid, *Pisidia dispar*, however it was removed from the graphical presentation of the final analyses as no other similar parasites were identified, and it merely mirrored the presence of its host so did not contribute to any better understanding of community structure.

The predators and scavengers were grouped as in this context the definitions are ambiguous, and many such species commonly switch roles according to available resources.

Suspension feeding organisms (= filter feeders) either actively pump suspended particles and organic matter through a filtration apparatus, or use complex feeding appendages including mucous nets, to separate such matter from the water column with the aid of bottom currents. Bivalve molluscs, tunicates and bryozoans are important suspension feeders, as are some crustaceans and polychaetes. The organic matter is typically living or dead phyto- and zooplankton and bacteria, resuspended benthic particles, and dissolved organic matter.

Deposit feeders may be either mobile or sedentary, and feed at or near the surface, or burrow to some depth. They feed on living or dead organic content, often including degraded plant material, and typically ingest sediment with its attached interstitial meiofauna and microflora. Deposit feeders typically process at least one body weight in sediment daily (Lopez & Levinton 1987), and considerable amounts of sediment are processed in this way. Many species switch between deposit- and suspension-feeding modes (Lopez & Levinton 1987). Switching is often influenced by local environmental variables (current flow, concentration of suspended particles). Interactions between deposit- and suspension-feeding animals influence nutrient cycling and community structure (Wilson *et al.* 1993).

Trophic status of each species was obtained from Poore & Rainer (1974), Fauchald & Jumars (1979), Brusca & Brusca (1990) and Todd (2001).

STATISTICAL METHODS

Between-sites similarity matrices, using the Bray-Curtis index on the untransformed data, were formed separately for the sediment, species-counts, and trophic structure data sets. Bray-Curtis was used because it does not derive similarity from conjoint absences (Clark & Warwick 1994), and has been shown to be a robust index across both raw and standardised data (Faith *et al.* 1987). These similarities formed the basis of group-average hierarchical clustering to produce dendrograms. Dissimilarities, calculated as one minus similarity, were used for a

multidimensional scaling (MDS) representation for each data set. The degree of association between the two between-sites similarity matrices (namely, using the sediment and the species-counts data respectively) was estimated using the Mantel test of the product-moment correlation. Canonical correspondence analysis (CCA) was used to derive and interpret the inter-relationships between these two sets of variables.

RESULTS

In total, a remarkable 564 species were collected (see Appendix 1) consisting of 11,892 individuals (average of 793 individuals/m²). Of these a large number (150) occurred only once, and only 264 species occurred at least 5 times. The fauna was relatively evenly represented across the three major taxa: Mollusca – 181 species (32.1%) of which the largest number was bivalves (108 spp.); Crustacea – 160 spp. (28.4%); and the Annelida – 180 spp. (31.9%). The Echinodermata were represented by relatively few species (16; 2.8%), though a couple of species played a major characterising role in some site communities.

Data Reduction. The large number of species recorded meant that a meaningful analysis of species correlations required some significant data reduction. Initial analyses were restricted to the 264 species which occurred 5 times or more. The biplot from the full CCA still showed too many species vectors to be interpretable, so this was re-run with only the 28 most abundant species. These 28 totalled 65% of all captures, and all other species represented less than 0.5% each. It was felt that this was reasonable to reflect the key species defining the communities

SITES CLASSIFICATION

The site groupings recognised here are the result of concordance between three separate site classifications based on: sediment structure vs sites; species presence and abundance vs sites; and trophic classes vs sites. The combined sites x sediments x species data were then shown in relationship to each other using a canonical correspondence analysis (CCA) biplot. Dendrograms of sediments and species site groupings (not presented here) largely revealed the same groupings as the MDS analyses,

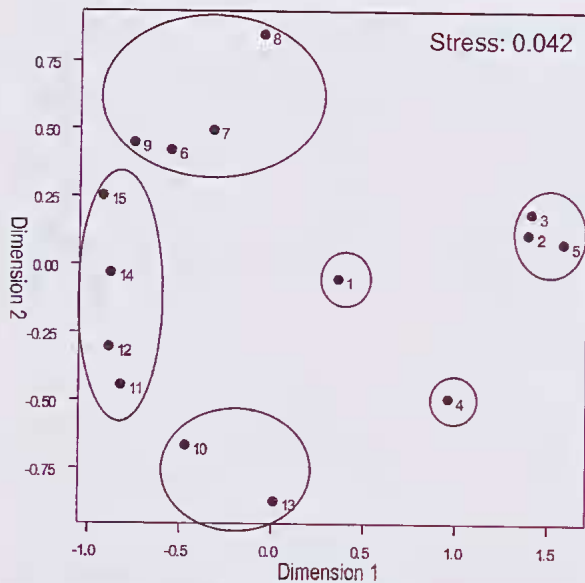


FIG. 3. MDS of sites x sediment data indicating 6 site-groupings (I–VI) based on relative proportions of sediment grades.

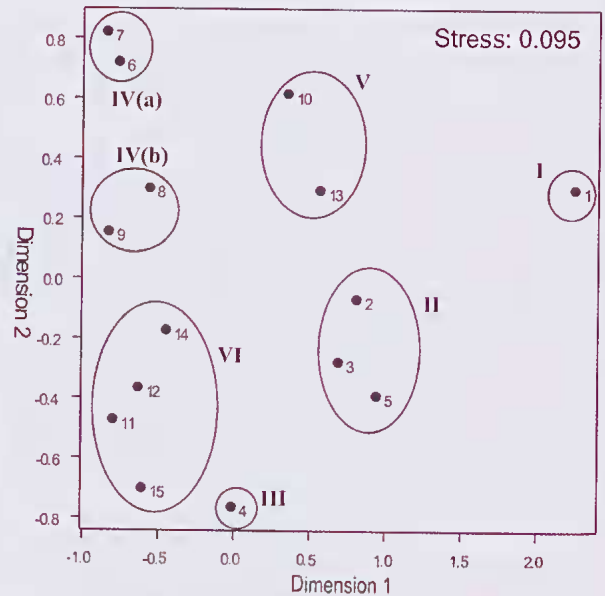


FIG. 4. MDS of spp. x sites classification showing seven discrete site-groups. Sites 6 & 7 and 8 & 9 are treated as Site-Group IVa and IVb respectively.

although a few sites that appear closer to each other in the MDS plots, moved into neighbouring clades in the dendrograms. Overall we considered the dendrograms did not give as conceptually a satisfying result probably because of the nature of the clustering algorithm, and that the MDS analyses gave a more visually understandable result in a two dimensional framework.

Under multidimensional scaling, two dimensions adequately represented these data, with stresses of much less than 0.2. These stress values were 0.042 for the sediments data, 0.021 for the trophic-level counts and 0.095 for the species-counts. These two-dimensional multidimensional patterns of sites are shown in Figs 2, 3 and 5 respectively.

The Mantel test showed a significant ($P < 0.01$) association between the similarity matrices, with a correlation of 0.51. The resultant biplot is shown in Fig. 6.

Sediments x Sites classification. The MDS of sites by sediment data (Fig. 3) suggests 6 site-groupings (I–VI) based on relative proportions of sediment grades. As found by Stephenson *et al.* (1974), sites 1 (Site-Group I) and 4 (Site-Group III) differ significantly from all other individual sites. The specific differences in sediment structure are explored in more detail under the

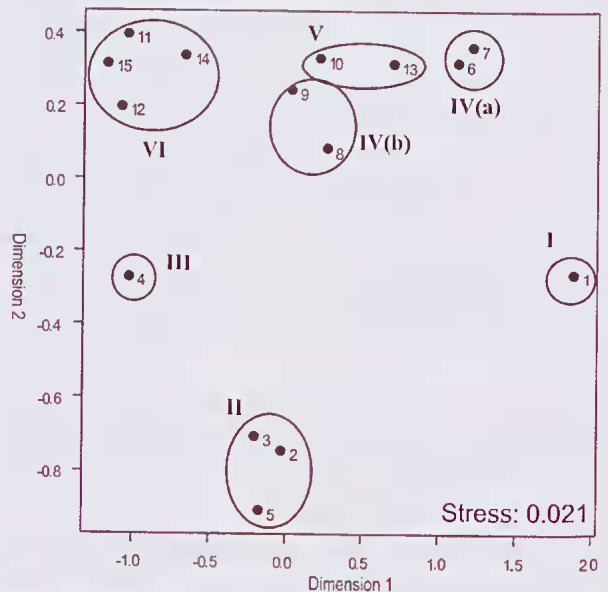


FIG. 5. MDS of trophic class x sites classification.

discussion of the trophic analysis. Noteworthy is that Sites 6, 7 & 9 clustered most closely together according to sediment composition with Site 8 being the outlier within the group. However, according to spp x sites and trophic structure x sites groupings, sites 6 & 7 are distinctly separated from 8 & 9, although relatively closely

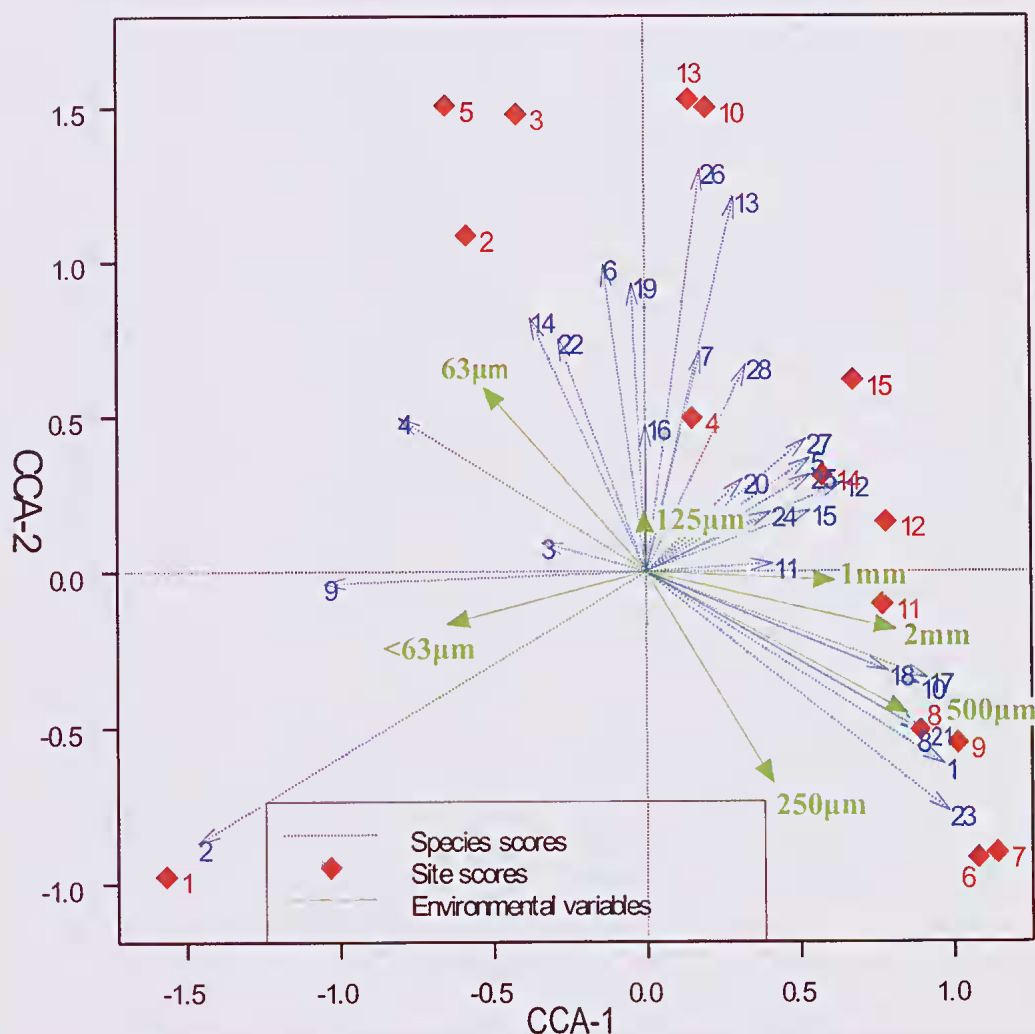


FIG. 6. CCA Biplot showing 3-parameter representation of species x sites x sediment characteristics.

allied. Because sites 6–9 are situated close together geographically, and thus form a logical site-grouping, we have decided to treat these four sites as a single site-group, but use a subgrouping notation to indicate that there are differences in species composition.

Species x Sites classification. The spp. x sites classification (Fig. 4) shows seven discrete site-groups, though as already mentioned, sites 6 & 7 and 8 & 9 are treated as Site-Group IVa and IVb respectively. Comparison with the map of sites (Fig. 2) shows that the site-groups all include sites that are clustered close to each other topographically.

Trophic Classes vs Sites classification. The analysis of trophic class x sites classification

(Fig. 5) essentially gives the same groupings as the species classification, and in particular sites 6, 7, 8, 9, 10 & 13 are clustered in close proximity (this is further discussed under a separate heading later).

CCA Biplot. This plot (Fig. 6) provides an informative 3-parameter visual representation of the species x sites x sediment characteristics. In general, the closer the arrow to the centre the more evenly distributed the values, such that inner cluster of species are the most widespread across all sites. Some strong trends in the data are apparent. Site 1 (Site-Group I) is strongly characterised by an increased proportion of 125 µm sediments and the marked presence of 'sp. 2' (*Mesochaetopterus minutus*). Sites 2, 3 and 5

(Site-Group II) have the greatest proportion of 63 μm sediments and are most strongly characterised by species 22 and 14 (*Whiteleggia stephensoni* and maldanid sp. 3 respectively). Species 4 (*Maldane* sp.) and 9 (*Golfingia trichiocephala*) are characteristic of both Site-Groups I and II. Site 4 (Site-Group III) is characterised by primarily 63 μm and 125 μm sediments but does not have an obvious species characterisation. Sp. 16 (spionid sp. 4) lies close to Site 4 on the plot, but this is an artefact of its dual presence at sites 2, 3, 5 (Site-Group II) and at the widely separated sites 6 and 7 (Site-Group IVa). Sites 6–9 (Site-Group IVa, b) are clearly characterised by much sandier sediment grades, and characterised by spp. 23 (*Pharyngeovalvata* sp.), 8 (*Terebellides narribri*), 1 (*Trichomya hirsuta*) and 17 (*Paraoroides* sp. 1). These associations are further discussed in the following Site-Group accounts.

SITE-GROUP CHARACTERISING SPECIES

The species \times sites classification largely agreed with the sediments \times sites classification in supporting the recognition of six major site-groups, however there was some disparity between the two pairs of adjacent sites within Site-Group 4, and this was resolved by erecting subgroups IVa and IVb for the purposes of understanding the dominant species that characterise these communities.

In order to limit discussion of characterising species for each site-group, we have arbitrarily assigned a cut-off of 10 or more individuals being present at least one site within the site-group. This count represents the sum of quintuplicate 0.1 m^2 grab samples, so in effect, we only further consider species composition at any given site if they occurred in a density greater than 2 individuals per grab sample. We feel intuitively that at densities lower than this any given species will be a minor component of the community at that site-group.

Where a species is discussed as uniquely characterising a site-group, this is based on the reduced data set. It is possible that such a species may occasionally occur in other site-groups, but in sufficiently low numbers as to not make a significant contribution to site-group classification.

Site-Group I. This site 'group' is composed only of Site 1. All analyses (see Figs 2, 3, 5 & 6) indicated that Site 1 was unique. This result

agreed with that of Stephenson *et al.* (1974) who, although they included it in their Site-Group I (with sites 2–5), remarked that it was aberrant. While it was a relatively muddy/fine sand site (49% 63 μm), it was not as obviously muddy as the adjacent sites otherwise included in Site-Group II (see Fig. 7). In total 95 spp. were present consisting of 2179 individuals (4358 m^{-2}), making it the most densely populated of all the sites. There were 16 characterising species (>10 individuals), but it was remarkable for very high densities of four species: *Mesochaetopterus minutus*, *Golfingia trichiocephala*, *Maldane* sp. and *Ophiura kinbergi*. In particular it was markedly different from all other sites by having a very large number of the tubicolous, suspension feeding polychaete *Mesochaetopterus minutus* (1986 m^{-2}), which occurred at no other site. The other most abundant species, the sipunculid *Golfingia trichiocephala*, characterised this site and Site-Group II, but nowhere else. The deposit feeding polychaete *Maldane* sp. also occurred at Site-Groups II, III, and V, but was three times more abundant at Site 1 than at the sites comprising Site-Group II, and at least six times or more abundant than at sites III and V. The predatory *Ophiura kinbergi* was the other major component of the dominant fauna, and is presumably responding to the number of prey species present.

Twelve species were present in relatively lower but consistent numbers. Of these, *Protankyra* sp., capitellid sp. 5 and polynoid sp. 4 are unique to this site; Amphiuridae sp. 1, Ophiuridae sp. 2, *Sternaspis scutata*, *Neumatoneis unicornis* and maldanid sp. 3 are characteristic of only this site and the adjacent Site-Group II, while *Ophiotlirix* sp 1 is shared only with Site-Group V. Overall it is clear this site shares its closest affinities with Site-Group II, but having four uniquely characteristic species, including the very abundant *Mesochaetopterus minutus*, sets it clearly apart faunistically. This species may have a patchy presence, or may be seasonal in occurrence, and without it, this site would be far more faunistically similar to Site-Group II. However there were also significant sediment differences, and this may, in the end, be the determining factor in the observed faunistic differences.

Table 3. Species characterising Site-Group I (Site 1). Trophic composition: 1, Suspension feeder; 2, Deposit feeder; 3, Grazer; 4, Predator/Scavenger.

Id.	Species	Phylum	Family	Trophic	Totals	Fidelity
2	<i>Mesochaetopterus minutus</i>	Annelida	Chaetopteridae	1	993	1/1
4	<i>Maldane</i> sp.	Annelida	Maldanidae	2	307	1/1
3	<i>Ophiura kinbergi</i>	Echinodermata	Ophiotrichidae	4	304	1/1
9	<i>Golfingia trichocephala</i>	Sipuncula	Golfingiidae	2	121	1/1
40	Amphiuridae sp 1	Echinodermata	Amphiuridae	4	32	1/1
45	<i>Ophiothrix</i> sp 1	Echinodermata	Ophiocomidae	1	20	1/1
56	Ophiuridae sp 2	Echinodermata	Ophiuridae	4	17	1/1
34	<i>Sternaspis scutata</i>	Annelida	Sternaspididae	2	16	1/1
80	<i>Protankyra</i> sp.	Echinodermata	Synaptidae	2	15	1/1
61	capitellid 5	Annelida	Capitellidae	2	13	1/1
39	<i>Nematonereis unicornis</i>	Annelida	Eunicidae	4	12	1/1
6	amphipod 02	Crustacea	—	4	11	1/1
14	maldanid 3	Annelida	Maldanidae	2	11	1/1
73	polynoid 4	Annelida	Polynoidae	4	11	1/1
7	<i>Ampelisca</i> sp.	Crustacea	Ampeliscidae	1	10	1/1
11	<i>Cheiriphotis</i> sp 1	Crustacea	Corophiidae	1	10	1/1

Site-Group II. Site-Group II includes sites 2, 3 and 5 (Figs 2, 3, 5, 6) and were the 'muddiest' sites (ca. 87% at 63 μ m), and this concurs with the earlier assessment of Stephenson *et al.* (1974). These three sites in total included 160 species and 2036 individuals, with an average of 105 spp. and 679 individuals (1358 m⁻²) per site. So, on a per site (area sampled) basis, there was a similar number of species to site 1, but total abundances were much lower (about one-third).

As already discussed, this Site-Group is closest faunistically to Site-Group I, and is geographically adjacent (Fig. 2). Fifteen species occurred in abundances >10 for at least one constituent site (Table 4). The four species with the highest fidelity to the group were also the most abundant, viz. *Maldane* sp., amphipod sp. 2, *Ophiura kinbergi* and maldanid sp. 3. Amphipod sp. 2 occurred in significant numbers not only at this site, but also relatively widely at other sites (Site-Groups I, IVb, V & VI), at abundances at least twice as high as Site-Group II. As already mentioned, the deposit feeding polychaete *Maldane* sp. is also at Site-Groups I, III, and V, but was only about one-third as abundant at Site 1 though still 2–3 times more abundant than at Site-Groups III and V. *Ophiura kinbergi* was again a dominant component of the fauna, but its wide occurrence across all site-groups, prevents the species

from characterising this site-group. *Golfingia trichocephala*, similarly to Site 1, also occurred in large numbers but at only two of the three sites in the group. Amphiuridae sp. 1, Ophiuridae sp. 2, *Sternaspis scutata*, *Nematonereis unicornis* and maldanid sp. 3 are all shared only with Site-Group 1. Of the other species, spionid sp. 4 only also occurs at Site-Group IVa; the maldanid sp. 2 is also at Site-Groups III and V; and *Eunice vittata* also occurs at Site-Group V. The tanaid, *Whiteleggia stephensoni* appears to be the only species to occur uniquely at this site-group, with a fidelity of 2 of the 3 sites, and this species and maldanid sp. 3 are clearly shown in the CCA Biplot (Fig. 6) to be most characteristic of this site-group. The presence of *Halophila spinulosa* was also noted at this site.

Site-Group III. Like Site-Group I, Site-Group III comprises only a single unique site (Site 4). It is characterised by a somewhat lower species richness (86 species), and relatively low abundances (332 individuals or 664 m⁻²). While having a smaller component of fine sediment (63 μ m) than Site-Group II, there was a higher proportion of 125 μ m sediment grade, and a negligible coarser sand component (see Fig. 7). Only seven species occurred in an abundance >10, and none stood out as having particularly high individual abundances. Like the adjacent Site-Group II,

Table 4. Species characterising Site-Group II (Sites 2, 3, 5). Trophic composition: 1, Suspension feeder; 2, Deposit feeder; 3, Grazer; 4, Predator/Scavenger.

Id.	Species	Phylum	Family	Trophic	Totals	Fidelity
4	<i>Maldane</i> sp	Annelida	Maldanidae	2	384	3/3
6	amphipod 02	Crustacea	—	4	177	3/3
3	<i>Ophiura kinbergi</i>	Echinodermata	Ophiotrichidae	4	124	3/3
14	maldanid 3	Annelida	Maldanidae	2	116	3/3
9	<i>Golfingia trichocephala</i>	Sipuncula	Golfingiidae	2	94	2/3
7	<i>Ampelisca</i> sp.	Crustacea	Ampeliscidae	1	57	2/3
16	spionid 4	Annelida	Spionidae	2	50	2/3
22	<i>Whiteleggia stephensoni</i>	Crustacea	Whiteleggiidae	2	49	2/3
11	<i>Cheiriphotis</i> sp 1	Crustacea	Corophiidae	1	42	2/3
19	maldanid 2	Annelida	Maldanidae	2	24	2/3
39	<i>Nematoneis unicornis</i>	Annelida	Eunicidae	4	15	1/3
56	Ophiuridae sp 2	Echinodermata	Ophiuridae	4	15	1/3
34	<i>Sternaspis scutata</i>	Annelida	Sternaspidae	2	14	1/3
29	<i>Eunice vittata</i>	Annelida	Eunicidae	4	12	1/3
40	Amphiuridae sp 1	Echinodermata	Amphiuridae	4	10	1/3

Maldane sp. and *Ophiura kinbergi* were among the more common species. However unlike Site-Groups I and II, *Trichomya hirsuta* is present. *T. hirsuta* is the dominant species at Site-Group IVa, b, and an important component of the community at Site-Group VI. Two polychaete species, *Nephtys australiensis* (predator) and maldanid sp. 5 (deposit feeder) were uniquely found at this site.

Site-Group IVa. Site-Group IVa consisted of only two sites (6 and 7), with a total of 178 species, and the highest average per site species diversity (av. 136 spp./site), and 2584 individuals; (av. 1292 individuals = 2584 m²). Site-Groups IVa and IVb together were characterised by large numbers of the clumping mussel, *Trichomya hirsuta*. This species grows to about 40 mm shell length and helps to structure the rest of the

community by providing habitat above the sediment. In particular, at Site-Group IVa *Trichomya* was the dominant animal occurring at an average density of 1760 m⁻². This may help explain why both these site-groups had the highest species diversity of any of the sites. The predatory polychaete, *Opisthosyllis* sp., was the next most abundant but also occurred at Site-Groups III, IVb, V and VI, so is not particularly diagnostic of this community. *Terebellides narribri*, *Pisidia dispar*, *Paraoroides* sp. 1, capitellid sp. 1, *Chama limbula*, and *Heteropilumnus fimbriatus* all characterised Site-Groups IVa and IVb, occurring nowhere else. Eleven species occurred uniquely at Site-Group IVa: syllid sp. 7, *Pharyngeovalvata* sp., nereid sp. 4, *Arca navicularis*, polynoid sp. 3, *Prionospio* sp. 1, sponge sp. 1, polynoid sp. 5, *Syllis* sp., *Barbatia foliata*, and *Eunice australis*.

Table 5. Species characterising Site-Group III (Site 4). Trophic composition: 1, Suspension feeder; 2, Deposit feeder; 3, Grazer; 4, Predator/Scavenger.

Id.	Species	Phylum	Family	Trophic	Totals	Fidelity
4	<i>Maldane</i> sp	Annelida	Maldanidae	2	34	1/1
1	<i>Trichomya hirsuta</i>	Mollusca	Mytilidae	1	32	1/1
3	<i>Ophiura kinbergi</i>	Echinodermata	Ophiotrichidae	4	21	1/1
33	<i>Nephtys australiensis</i>	Annelida	Nephtyidae	4	18	1/1
53	maldanid 5	Annelida	Maldanidae	2	14	1/1
19	maldanid 2	Annelida	Maldanidae	2	13	1/1
5	syllid 1 [<i>Opisthosyllis</i> sp.]	Annelida	Syllidae	4	10	1/1

Table 6. Species characterising Site-Group IVa (Sites 6, 7). Trophic composition: 1, Suspension feeder; 2, Deposit feeder; 3, Grazer; 4, Predator/Scavenger.

Id.	Species	Phylum	Family	Trophic	Totals	Fidelity
1	<i>Trichomya hirsuta</i>	Mollusca	Mytilidae	1	880	2/2
5	syllid 1 <i>Opisthosyllis</i> sp	Annelida	Syllidae	4	140	2/2
8	<i>Terebellides narribri</i>	Annelida	Terebellidae	2	130	2/2
10	<i>Pisidia dispar</i>	Crustacea	Porcellanidae	1	106	2/2
11	<i>Cheiriphotis</i> sp 1	Crustacea	Corophiidae	1	78	2/2
3	<i>Ophiura kinbergi</i>	Echinodermata	Ophiotrichidae	4	73	2/2
23	syllid 7 <i>Pharyngeovalvata</i> sp	Annelida	Syllidae	4	68	2/2
21	nereid 4	Annelida	Nereididae	4	55	2/2
17	<i>Paraoroides</i> sp 1	Crustacea	Corophiidae	1	51	2/2
18	capitellid 1	Annelida	Capitellidae	2	36	2/2
31	<i>Arca navicularis</i>	Mollusca	Arcidae	1	34	2/2
16	spionid 4	Annelida	Spionidae	2	30	2/2
15	cirratulid 1, <i>Tharax</i> sp	Annelida	Cirratulidae	2	23	2/2
51	polynoid 3	Annelida	Polynoidae	4	22	2/2
38	<i>Prionospio</i> sp 1	Annelida	Spionidae	2	17	1/2
36	<i>Chama limbula</i>	Mollusca	Chamidae	1	16	1/2
12	<i>Gammaropsis</i> sp.	Crustacea	Isaeidae	1	14	1/2
71	sponge 1	Porifera	—	1	14	1/2
82	polynoid 5	Annelida	Polynoidae	4	13	1/2
47	<i>Heteropilumnus fimbriatus</i>	Crustacea	Pilumnidae	4	12	1/2
7	<i>Ampelisca</i> sp.	Crustacea	Ampeliscidae	1	12	1/2
42	syllid 5 <i>Syllis</i> sp	Annelida	Syllidae	4	11	1/2
52	nematode	Nematoda	—	2	11	1/2
86	<i>Barbatia foliata</i>	Mollusca	Arcidae	1	10	1/2
48	<i>Eunice australis</i>	Annelida	Eunicidae	4	10	1/2

Site-Group IVb. Placed geographically adjacent to IVa, it also consisted of only two sites (8 and 9), and had a very high species diversity, with a total of 155 species (av. 112/site), and 1443 individuals; (av. 722 individuals = 1444 m⁻²). As with Site-Group IVa the most conspicuous faunal component was *Trichomya hirsuta*, though the abundance was a little less than a third of Site-Group IVa. Species composition in general was very similar to Site-Group IVa, though generally lower numbers and fewer species occurring in abundances >10. Of this category only three species were 'unique' to the site-group, viz., syllid sp. 2, capitellid sp. 3 and spionid sp. 7. Another species, capitellid 2 was uniquely shared with Site-Group VI.

Site-Group V. This site-group also consisted of only two sites (10 and 13) either side of the wide channel separating Site-Group IV(a, b)

and Site-Group VI (see Fig. 2). It had a similarly high species diversity (156 spp.) to Site-Group IVb with a total of 1849 individuals collected (1484–2214 m⁻²). Each site averaged averaged 114 spp. and 925 individuals. The obvious difference separating this site-group from Site-Group IV(a, b) is the absence of *Trichomya hirsuta*. Of the species with abundance >10, only 7 species occurred at both sites.

Unique to this site-group is *Byblis* sp. 3 which occurred at both sites in large numbers and probably helped contribute to its separation. Also unique to the site-group, but found at only one site in the pair were nine other species: *Solen vaginoides*, amphipod sp. 4, *Magelona dakini*, *Ophiocomella sexradia*, paraonid sp. 2, *Goniada* sp., *Konarus cheiris*, Sphaeromatidae sp. 6 and Sphaeromatidae sp. 7. The cirratulid sp. 1 (*Tharax* sp.) was only at Site 10 and shared with the closest sites in Site-Group IV (a, b).

Table 7. Species characterising Site-Group IVb (Sites 7, 8). Trophic composition: 1, Suspension feeder; 2, Deposit feeder; 3, Grazer; 4, Predator/Scavenger.

Id.	Species	Phylum	Family	Trophic	Totals	Fidelity
1	<i>Trichomya hirsuta</i>	Mollusca	Mytilidae	1	258	2/2
8	<i>Terebellides narribri</i>	Annelida	Terebellidae	2	115	2/2
3	<i>Ophiura kinbergi</i>	Echinodermata	Ophiotrichidae	4	66	2/2
10	<i>Pisidia dispar</i>	Crustacea	Porcellanidae	1	53	2/2
5	syllid 1 <i>Opisthosyllis</i> sp	Annelida	Syllidae	4	44	2/2
15	cirratulid 1, <i>Tharax</i> sp	Annelida	Cirratulidae	2	42	2/2
11	<i>Cheiriphotis</i> sp 1	Crustacea	Corophiidae	1	38	2/2
18	capitellid 1	Annelida	Capitellidae	2	32	2/2
12	<i>Gammaropsis</i> sp.	Crustacea	Isaeidae	1	30	2/2
41	spionid 1	Annelida	Spionidae	2	26	2/2
17	<i>Paraoroides</i> sp 1	Crustacea	Corophiidae	1	25	2/2
46	syllid 2	Annelida	Syllidae	4	29	1/2
58	capitellid 3	Annelida	Capitellidae	2	22	1/2
20	capitellid 2	Annelida	Capitellidae	2	13	1/2
47	<i>Heteropilumnus fimbriatus</i>	Crustacea	Pilumnidae	4	12	1/2
36	<i>Chama limbula</i>	Mollusca	Chamidae	1	12	1/2
66	spionid 7	Annelida	Spionidae	2	12	1/2
6	amphipod 02	Crustacea	—	4	12	1/2
32	Chitons (unidentified)	Mollusca	—	3	11	1/2
7	<i>Ampelisca</i> sp.	Crustacea	Ampeliscidae	1	10	1/2

Site-Group VI. This is a cluster of four sites (11, 12, 14, 15) situated on the northern end of the Banana Banks (Fig. 2), in generally shallower water (3.1–4.3 m at high tide), and while not tidally exposed, would be only under 1–2 metres of water at low tide. It was also characterised by the presence of seagrasses (mainly *Halophila* species). Overall this site-group had the highest species diversity (193 spp.), but only a moderate per site diversity (av. 91 spp./site). Of these 193 species only 14 occurred in abundances of 10 or more across the group. Thus, most species at this site-group occurred in relatively low numbers, and with a large number of single species occurrences at one or more sites. In total 1469 individuals were collected at an average of 367 per site (734 m⁻²), so abundances were generally lower than at other sites.

Only the suspension feeding anomuran crustacean, *Pisidia dispar*, showed complete fidelity to all four sites. As for Site-Groups III and IV, *Trichomya hirsuta* was present at three sites but in relatively lower numbers. All of the other high fidelity species (3/4 sites) had broad-

ranging occurrences across a number of other site-groups. A number of species were only found at this site-group, but all had low fidelity (1/4 sites), viz. *Pupa* sp., *Macrophiiothrix* sp. 1, *Magelona 'papillicornis'*, and *Eusarsiella* sp. 1.

PATTERNS IN TROPHIC STRUCTURE

The faunal taxonomic composition and an analysis of trophic structure within the site-group communities in our study area are presented here. The MDS analysis of trophic class x sites classification (Fig. 5) essentially gives the same groupings as the species classification, and in particular sites 6, 7, 8, 9, 10 & 13 (Site-Groups IV & V) are clustered in close proximity. These sites are the closest geographically, although interestingly Site-Group V differs significantly from Site-Group IV in sediment structure (Fig. 7), though this apparently is not reflected as a marked difference in trophic composition.

The Predator/Scavenger component made up the greatest percentage of species (nearly 40%) but was lower in total abundance than the other two major feeding guilds (Table 10). The Deposit Feeders comprised the next most speciose

Table 8. Species characterising Site-Group V (Sites 10, 13). Trophic composition: 1, Suspension feeder; 2, Deposit feeder; 3, Grazer; 4, Predator/Scavenger.

Id.	Species	Phylum	Family	Trophic	Totals	Fidelity
3	<i>Ophiura kinbergi</i>	Echinodermata	Ophiotrichidae	4	198	2/2
7	<i>Ampelisca</i> sp.	Crustacea	Ampeliscidae	1	164	2/2
13	<i>Byblis</i> sp 3	Crustacea	Ampeliscidae	1	157	2/2
6	amphipod 02	Crustacea	—	4	110	2/2
12	<i>Gammaropsis</i> sp.	Crustacea	Isaeidae	1	54	2/2
19	maldanid 2	Annelida	Maldanidae	2	32	2/2
11	<i>Cheiriphotis</i> sp 1	Crustacea	Corophiidae	1	26	2/2
5	syllid 1 <i>Opisthosyllis</i> sp	Annelida	Syllidae	4	178	1/2
4	<i>Maldane</i> sp	Annelida	Maldanidae	2	98	1/2
26	<i>Solen vaginoides</i>	Mollusca	Solenidae	1	51	1/2
30	amphipod 04	Crustacea	—	4	31	1/2
15	cirratulid 1 (<i>Tharax</i> sp.)	Annelida	Cirratulidae	2	24	1/2
25	<i>Magelona dakini</i>	Annelida	Magelonidae	2	17	1/2
45	<i>Ophiolithrix</i> sp 1	Echinodermata	Ophiocomidae	1	16	1/2
95	<i>Ophiocomella sexradia</i>	Echinodermata	Ophiocomidae	1	16	1/2
98	paraonid 2	Annelida	Paraonidae	2	15	1/2
28	<i>Goniada</i> sp.	Annelida	Goniadidae	4	13	1/2
123	<i>Konarus cheiris</i>	Crustacea	Leptocheliidae	2	12	1/2
29	<i>Eunice vittata</i>	Annelida	Eunicidae	4	12	1/2
131	Sphaeromatidae sp. 6	Crustacea	Sphaeromatidae	4	12	1/2
152	Sphaeromatidae sp. 7	Crustacea	Sphaeromatidae	4	10	1/2

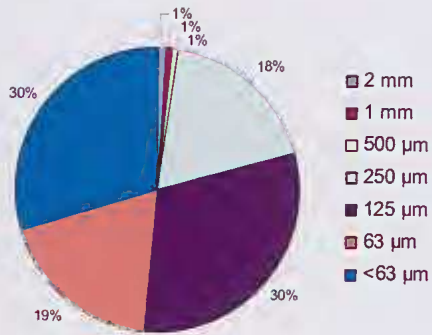
Table 9. Species characterising Site-Group VI (Sites 11, 12, 14, 15). Trophic composition: 1, Suspension feeder; 2, Deposit feeder; 3, Grazer; 4, Predator/Scavenger.

Id.	Species	Phylum	Family	Trophic	Totals	Fidelity
1	<i>Trichomya hirsuta</i>	Mollusca	Mytilidae	1	104	3/4
12	<i>Gammaropsis</i> sp.	Crustacea	Isaeidae	1	72	3/4
10	<i>Pisidia dispar</i>	Crustacea	Porcellanidae	1	71	4/4
3	<i>Ophiura kinbergi</i>	Echinodermata	Ophiotrichidae	4	71	3/4
20	capitellid 2	Annelida	Capitellidae	2	34	3/4
5	syllid 1 <i>Opisthosyllis</i> sp	Annelida	Syllidae	4	49	2/4
7	<i>Ampelisca</i> sp.	Crustacea	Ampeliscidae	1	38	2/4
6	amphipod 02	Crustacea	—	4	31	2/4
35	<i>Pupa</i> sp.	Mollusca	Acteonidae	4	15	1/4
68	<i>Macrophiolithrix</i> sp 1	Echinodermata	Ophiotrichidae	4	13	1/4
32	Chitons (unidentified)	Mollusca	—	3	11	1/4
49	caprellid 3	Crustacea	—	4	10	1/4
91	<i>Magelona 'papillicornis'</i>	Annelida	Magelonidae	2	10	1/4
50	<i>Eusarsiella</i> sp 1	Crustacea	—	4	10	1/4

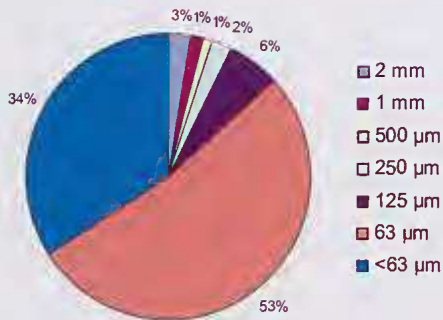
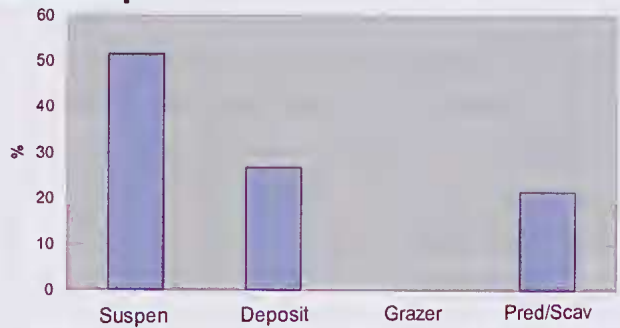
group, and although the Suspension Feeders had a slightly lower species richness again, they clearly dominated the fauna in terms of total abundance.

It is evident from Fig. 7 that the most interpretable faunal trophic response occurred in Site-

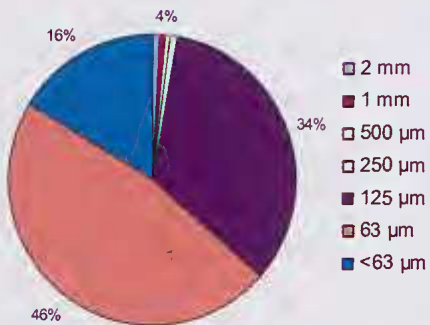
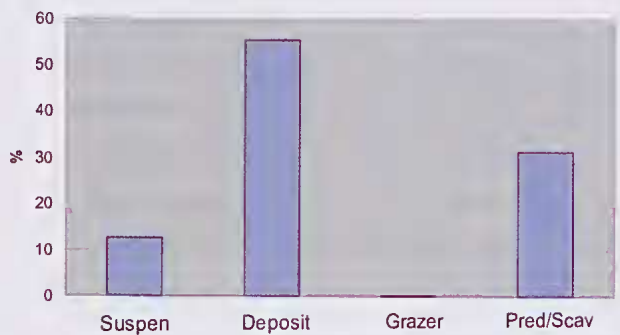
Groups II & III where deposit feeders dominated the species composition, and their magnitude appears directly proportional to the size of the 63 µm sediment fraction. Site-Group II (Sites 2, 3 & 5) has 87% of the retained sediment in the



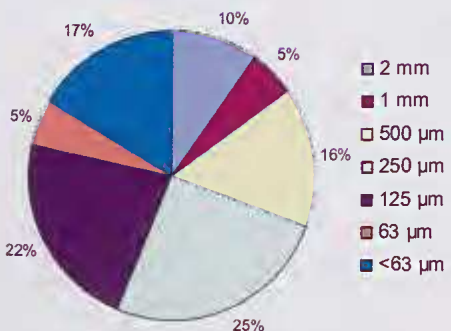
Site-Group I



Site-Group II



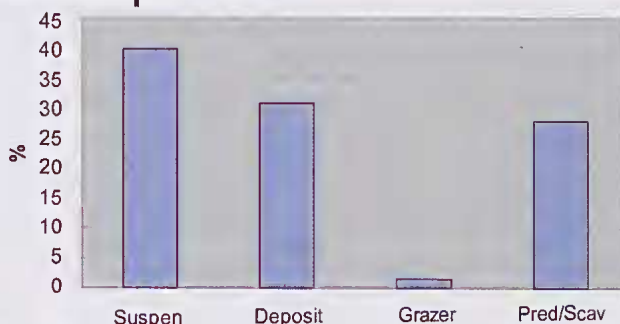
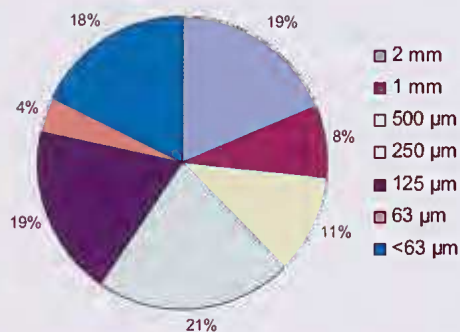
Site-Group III



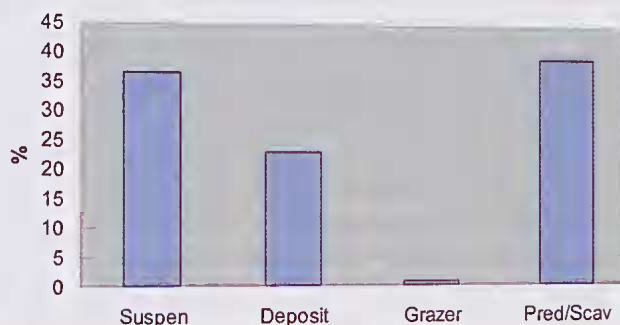
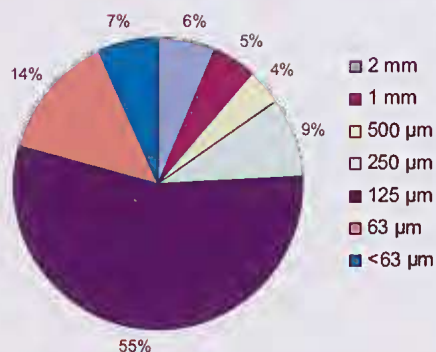
Site-Group IVa



Site-Group IVb



Site-Group V



Site-Group VI

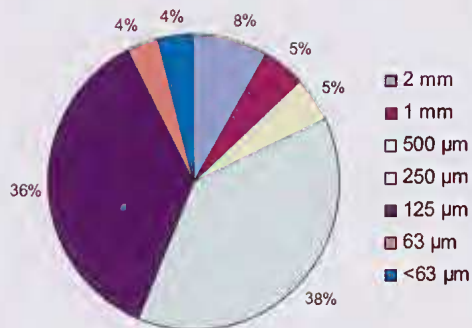


FIG. 7. Graphical presentation of average sediment composition compared with trophic categories for each site-group.

63 µm fraction, and 56% deposit feeders (the included sites are the same ones as those that Stephenson *et al.* (1974) recorded as having >50% mud). Similarly Site-Group III (Site 4) has 35% deposit feeders (compared to 23% suspension) and this corresponds with a smaller 63 µm fraction (62%). Thus it seems that the magnitude of the 63 µm fraction is a reasonable biological predictor for the switch from deposit feeding dominated communities to suspension feeding domination (finer sediments being more likely

to choke suspension feeding mechanisms). Poore & Rainer (1979: 483) similarly noted that all numerically important species in muddy environments in Port Phillip Bay are deposit feeders, and deposit feeders comprise 'a major portion of the biomass' in these habitats.

All other site-groups are dominated by suspension feeders. There does not seem to be a direct correlation with coarser sediment fractions, but the next 'muddiest' Site-Group I has approx. 49% 63 µm fraction, with suspension feeders

Table 10. Species composition and abundance according to trophic structure.

Trophic Type	No of Spp.	% of all Spp.	Abundance	% Total Abundance
Suspension Feeders	145	25.8%	4547	38.3%
Deposit Feeders	161	28.6%	3506	29.6%
Grazers	21	3.7%	111	0.9%
Predator/Scavengers	220	39%	3176	26.8%
Parasite	1	0.2%	21	0.2%
Unallocated	16	2.8%	501	4.2%

comprising approximately 52% of the faunal composition against the deposit feeders at 27%.

Away from the obviously muddy sites (1, 2, 3, 5) the relative proportions of deposit and suspension feeders is relatively predictable (deposit feeders varying from about 18–31%, av. 25%; and suspension feeders comprising 37–54%, av. 44%).

Predators/Scavengers are generally well represented in all site-groups but numbers are a little less predictable ranging from 22–41% (av. 31%). Given the high species abundances and diversity at most sites, the abundance and variety of predator species will also no doubt rise and fall with potential prey. Numbers will also be affected by the presence of seagrass communities, and by mollusc aggregations such as the mussel, *Trichomya hirsuta*, which, as ecosystem engineers, provide complex 3-dimensional epibenthic niches. The predatory ophiuroid, *Ophiura kinbergi*, is known as an indicator species for fine-sandy mud substrates, particularly for sites 1–5 (Stephenson *et al.* 1974). In the present study the species appears to reach its highest numbers in these muddier sites, but nevertheless it was also present as a significant component (< 10 individuals) of all site-groups in the present study.

DISCUSSION

WHAT IS THE TRUE DIVERSITY IN THE STUDY AREA?

While 564 species were collected during the course of the present survey, does this adequately reflect the true diversity of these sandy-mud environments to the south of Peel Island? Site-Group IVa had an average of 136 species at each site (sampling surface area of 0.5 m²/site), but the species presence was not identical, and the total count for both sites

(sampling surface area of 1 m²) had an additional 42 species represented. Similarly for Site-Group VI, the four included sites each had an average of 91 spp./site, but the cumulative total was 193 species (an additional 22 new species (ca. 25%) added per site). Many of these are 'rare' species represented by only 1–2 specimens, but given the simple species x area curve principle, on these figures one could expect increased sampling to increase the numbers of species significantly before there would be any obvious levelling off. Many of these extra species may also be already represented in other Site-Groups as well. However, given the differences in sediment profiles between the site-groups, and clearly different characterising species in each community, it still seems reasonable to expect that there is a significant under-representation of the number of species really present. This is further reinforced by the fact we only sorted and identified the fauna retained by a 1 mm sieve (generally most modern studies consider the macrobenthos to be > 0.5 mm), such that a significant component of the smallest macrobenthic fauna has not been sampled. Also, although it cannot be accurately quantified without significantly more work, it is clear that Stephenson *et al.* (1974) recorded a significant number of species not found in the present study. Finally, our study was a single season 'snapshot' and changes in communities over the course of a year, and between years, will undoubtedly add to the total species counts. On this basis, it seems reasonable to expect the number of macrobenthic species in this small area to approach 700. Such high species diversity is a good indication that the present communities in this area are healthy and resilient.

Davie & Hooper (1998) recorded 2512 invertebrates from the Bay, so the present tally from a

relatively few grab samples of the soft sandy-mud habitats south of Peel Island, actually represents 22.5% of this total. It is also noteworthy that many of the present unidentified taxa are likely to be new species. For example, the tanaid fauna of Moreton Bay now includes 29 species in 20 genera. However 20 of these have been described as new since 2006, including 6 new genera (Gutu 2006; Błażewicz-Paszkowycz & Bamber 2007; Bamber 2008). Such a pattern of discovery will no doubt repeat for many other groups, as most have received relatively scant attention from taxonomists.

DIVERSITY COMPARISONS WITH OTHER AREAS

A similar one-off study was undertaken by Long & Poiner (1994) in the Gulf of Carpentaria. Their study also used a 0.1 m² grab (Smith-McIntyre) and a 1 mm sieve size. In total they sampled 105 stations with 3 replicates per station (total of 315 samples across the entire gulf area). They found 7928 animals representing 684 taxa, with an average maximum abundance of 1527 m⁻² and a maximum average of 53.5 species/0.1 m². This can be compared with the present results where we found 564 species, but in relatively much higher abundances (11,892 individuals at an average of 1586 individuals/m² up to a maximum of 4358 m⁻² at Site 1); and a greater maximum number of species (137) at any specific site. Though there were fewer species recorded overall in the present study, it must be remembered that the total area sampled across the Gulf of Carpentaria was 300,000 km² versus the 3 km² of our sampling area in Moreton Bay.

The study of Long & Poiner (1994) also found that only about 36% of their taxa were represented by at least 5 individuals, and there was a high incidence of rarity with 36% of species represented by a single individual only. In our present Moreton Bay study we had a relatively greater diversity of species represented at abundances of 5 or greater (47% or 264 spp.), and a slightly lower percentage of single occurrences (27% or 150 spp.).

Another comparison of relative species diversity can be made with the intensively studied Port Phillip Bay, Victoria. There, there has been only 680 macrobenthic invertebrate species recorded across a much larger area (total area of 1950 km² versus 3 km² in the Moreton Bay

study area), and over multiple seasons and years (Poore & Rainer 1974, 1979; Poore 1993; Harris *et al.* 1996). By any standard, the study area south of Peel Island, in Moreton Bay, must be considered extremely rich.

DIFFERENCES IN COMMUNITY COMPOSITION SINCE 1970

Stephenson *et al.* (1974) reported a total of 394 faunal species from 8 sampling times, whereas in the present study we recorded 564 species from a single February sampling. While this outwardly appears to be a significantly higher diversity there are a number of factors that indicate the earlier study had underestimated the species present. Perhaps the most important factor was the level of scrutiny the samples received. Stephenson *et al.* (1974) stated: 'The normal method of collecting the biota from grab samples was by on-board wet sieving, with the final apertures ca. 1.2 mm square. Particular care was taken over samples containing small specimens of bivalves and gastropods which fortunately were infrequent.' Apparently all faunal sorting was undertaken on the boat, and there was no fine microscopic sediment sorting back in the laboratory (Stephen Cook, pers. comm.). While this was perhaps necessary at that time for logistical reasons, it would inevitably have led to a significant undersampling of the smaller faunal component.

Another difficulty in making a direct comparison between the two studies is that we have no access to the original individual sampling-times data of Stephenson *et al.* (1974). The data presented in their paper is in summary form only, and either gives accumulated totals or average values for the whole two-year sampling period. Given that seasonal communities exist, we are therefore unable to make direct summer community comparisons because of this lack of specific seasonal data.

Stephenson *et al.* (1974) specifically stated that they did not include amphipods 'Because of anticipated difficulties in identification and in recognition of species ... Amphipods were present in smaller numbers than in comparable surveys elsewhere, but nevertheless their omission is unfortunate.' Their assertion that amphipods were present in smaller numbers is perhaps also a comment on their less than desirable sorting

Table 11. A comparison of results for site-groupings and characterising species for Stephenson *et al.* (1974), and the presently reported 2005 sampling. VHC = very high conformity (or high fidelity to that site group); HI = high importance (high abundances in that site group). Species listings are not exhaustive — see text in Results for a more extensive analysis.

1970 Sites	Site Grp	Characterising Species	2005 Sites	Site Grp	Characterising Species
1, 2, 3, 5	IV	<i>Lygdanis</i> (VHC) <i>Tucetilla</i> (VHC) <i>Molgula rima</i> (VHC) <i>Polycarpa fungiformis</i> (VHC) <i>Glycera americana</i> (HI) <i>Paphia gallus</i> (HI) <i>Thermiste</i> sp. (HI) <i>Polycarpa fungiform</i> (HI)	1, 2, 3, 5	I & II	<i>Mesochaetopterus minutus</i> (VHC)(HI) <i>Golfingia trichocephala</i> (VHC) (HI) maldanid 3 (VHC) Amphiuridae sp. 1 (VHC) Ophiuridae sp. 2 (VHC) <i>Sternaspis scutata</i> (VHC) <i>Neuatoiereis unicornis</i> (VHC) amphipod sp. 2 (HI) <i>Maldane</i> sp. (HI) <i>Ophiura kinbergi</i> (HI)
4, 12, 14	III	sabellid 4 (VHC) <i>Euclymene</i> spp. (VHC)(HI) <i>Isolda</i> (VHC) <i>Petaloproctus</i> (VHC)(HI) <i>Circe</i> (VHC) <i>Malleus</i> (VHC) <i>Eunice antennata</i> (HI)	4	III	<i>Neplitys australiensis</i> (VHC) maldanid sp. 5 (VHC) <i>Maldane</i> sp. (HI) <i>Trichomya hirsuta</i> (HI) <i>Ophiura kinbergi</i> (HI)
6, 7, 8, 9, 10, 13	II	<i>Tellina lilium</i> (VHC) <i>Protankyra</i> sp. (VHC) <i>Microcosmos</i> (VHC) <i>Ensiculus</i> (HI) <i>Protankyra</i> (HI)	6, 7, 8, 9	IVa IVb	<i>Terebellides narribri</i> (VHC) <i>Pisidia dispar</i> (VHC) <i>Pluatyngaeovalvata</i> sp. (VHC) nereid 4 (VHC) <i>Paraoroides</i> sp. 1 (VHC) capitellid sp. 1 (VHC) <i>Chama limbula</i> (VHC) <i>Heteropilumnus fimbriatus</i> (VHC) <i>Trichomya hirsuta</i> (HI) <i>Opisthosyllis</i> sp. (HI) <i>Cheiriphotis</i> sp. 1 (HI) <i>Ophiura kinbergi</i> (HI)
			10, 13	V	<i>Byblis</i> sp. 3 (VHC)(HI) <i>Ophiura kinbergi</i> (HI) <i>Ampelisca</i> sp. (HI) amphipod sp. 2 (HI) <i>Gammaropsis</i> sp. (HI) maldanid 2 (HI) <i>Cheiriphotis</i> sp 1 (HI)
11, 15	I	<i>Leocrates</i> (VHC) <i>Ophiura kinbergi</i> (VHC) <i>Rhizopa</i> (HI)	11, 12, 14, 15	VI	<i>Trichomya hirsuta</i> (HI) <i>Gammaropsis</i> sp. (HI) <i>Pisidia dispar</i> (HI) <i>Ophiura kinbergi</i> (HI) capitellid 2 (HI)

strategy. In the present survey, amphipods were a significant component of the fauna with 47 species recorded. In support of this contention that the sorting was at fault, it appears that the peracarid crustaceans in general were massively undersampled by the earlier study. Stephenson

et al. (1974) recorded only two tanaids (*versus* 10 spp. in present study), three cumaceans (*versus* 11 spp.) and no isopods (*versus* 31 spp.). We did not include algae in the present study, whereas Stephenson *et al.* (1974) recorded 24 species — therefore no comparison can be made. The presence

of seagrasses (primarily *Halophila* species) was merely noted as present or absent in both studies.

There were however some major differences between the two surveys that need discussion. We recorded no tunicates at all, whereas Stephenson *et al.* (1974) recorded 27 species, including eight that were sufficiently common to contribute to their sites and times classifications. In fact, two species, *Molgula rima* and *Polycarpa fungiformis* showed very high conformity to their Site-Group IV ('Southern shallows' sites). Similarly, for their site-groups II and III *Polycarpa pedunculata* showed high conformity. Stephenson *et al.* (1974) did note that seasonality was a factor in the presence of tunicates, and this was further discussed in detail by Kott (1972) who re-examined their original data. Kott (1972: 254, Table 1) clearly shows that in March 1970 only seven species were recorded from all sites, while in March 1971, this had dropped to four (three fixed-substrate species, and only a single free-living species). In both years all species were present in very low numbers. *Molgula* species in particular are highly seasonal, appearing in significant numbers only during the winter months from May to August. Kott (1972) clearly showed that *Molgula rima* was absent from both March samplings of Stephenson *et al.* (1974) (as was the related species, *M. exigua*). She considered that *M. rima* individuals probably have a life-span of less than 6 months, and recruitment to areas such as the 'Southern shallows' is likely to be from persistent populations in adjacent areas. This would explain the absence of *M. rima* and related species from the present February 2005 survey results. Similarly, while the two *Polycarpa* species, *P. fungiformis* and *P. pedunculata*, were present in the 1970/1971 survey, they were also in low numbers. These species both require suitable hard substrate to attach to, and therefore there is an element of chance that such substrates might be missed in any random grab-sampling. Kott (1972) also believed that there is annual mortality of larger breeding individuals, of these species and that *P. pedunculata* does not occur in sufficient densities for a self sustaining breeding population, and would rely on external recruitment.

Another conspicuous difference between the studies was the relatively large number of larger crustaceans recorded by Stephenson *et al.*

(1974) — 50 species of Stomatopoda and Decapoda, including 37 species of crabs. The present study found 31 species, of which 20 were crabs. This could be reasonably explained by a slow incremental increase of 'rare' species, given there were seven additional sampling events over all seasons in the earlier study..

CHANGES TO SITE-GROUPS AND CHARACTERISING SPECIES

Stephenson *et al.* (1974) defined four major site-groups based on their species x sites classification, viz. I (sites 11, 15); II (sites 6, 7, 8, 9, 10, 13); III (sites 4, 12, 14); and IV (sites 1, 2, 3, 5). The major difference with the present results is the similarity of sites 11 and 15 as separate from the other two 'southern shallows' sites 12 and 14 — in the present study these four sites were all linked into our single site-group VI. In the earlier study sites 4, 12 and 14 also were the most similar in terms of sediment composition, and somewhat muddier than sites 11 and 15, whereas in the present study the sediment composition was more similar between the southern sites, and in particular quite similar between adjacent sites 11 and 12, while site 4 (our site-group III) was one of the muddiest sites, and most similar to sites 2, 3, and 5 (our site-group II). Otherwise, we further separated sites 10 and 13 into a separate site-group V, and recognised site 1 as being faunistically distinctive from the adjacent sites 2, 3, and 5 (our site-group II).

As can be seen from Table 11, there is almost no correspondence between the species that defined the site communities in 1970 and those present in 2005, either in terms of conformity to a site group, or in relative abundances. One major change appears to have been the development of beds of the hairy mussel, *Trichomya hirsuta*, at different densities within the western part of the study area along the 'Northwest gutter' (6–10, 13), and the 'Southern shallows' (11, 12, 14, 15). While this species was recorded in the earlier study, it must have been present in only very small numbers, whereas in 2005 it was the dominant animal at a number of sites, both in abundance and biomass.

BROADER DETERMINANTS OF COMMUNITY STRUCTURE

Stevens & Connolly (2005) undertook a broad study of benthic habitat mapping within the

Bay using video techniques. They included the current sites in their 'Habitat Group D', which included 10 sites, and also extended inshore to the north-west of Peel Island towards the Brisbane River. This area was loosely characterised as their 'inshore algae and sponge' habitat-group, and was the most taxon-rich (42 species) of all the habitat-groups they recognised. Although visually dominated by algae and sponges, they noted significant contributions from solitary ascidians, anemones, and seagrass. Despite the present sites being in the central part of this generalised 'community' it is interesting to note that sponges and ascidians were an insignificant component of the present grab-sampling. The Stevens & Connolly (2005) study was however based on a different scale and was based on identification and counts of macroscopic epibenthic fauna.

There is now an increasing understanding of broad scale community patterns within Moreton Bay (see for example, Davie & Hooper 1998; Skilleter 1998; Stevens & Connolly 2005). The major pattern to emerge shows high species numbers occurring around the mouth of the Brisbane River and along the western shores of the Bay, gradually diminishing to the north and east. There is also a marine dominated zone comprising two distinct centres of high diversity – one around the northern end of Stradbroke Island (including Myora), Peel, Bird and Goat Islands, where there is a shift to consolidated bottoms and reefal species; and a second area around Middle Banks and Tangalooma. The clean labile sands of the northern and eastern openings are extremely species poor. In general species richness is highest in areas of relative stability and with favourable hydrographic-sedimentary conditions, and this is emphasised by Poiner's (1979) two year study of sand and seagrass communities of the Sholl Bank, north-eastern Moreton Bay. He found that the biota of the sand communities was relatively depauperate, in a continual state of flux, and showed no evidence of a stable climax community. In contrast, seagrass communities were species-rich and relatively stable.

Inshore communities however, especially in the southern half of the bay, are significantly influenced by the four major rivers and

numerous creeks that feed into the Bay – presumably providing an overlay of nutrient rich sediments and a variety of sediment particle sizes which would support a variety of feeding types. Annual or unpredictable flood events also add an element of instability to the fauna of this region, and this combined with regular 'fertilisation' presumably stimulates recruitment and encourages high diversities. Stephens (1992) calculated that the Brisbane River supplies mud to Moreton Bay at a minimum rate of 175,000 tonnes/yr. Flood events also lead to increased productivity in estuarine and inshore oceanic waters as a result of the influx of vitamins and nutrients (Copeland 1966).

Sediment characteristics have long been recognised as presenting a complex of limiting values influencing the distribution of benthic fauna (e.g. Rhoads 1974; Kay & Knights 1975; Coleman & Cuff 1980; Lopez & Levinton 1987). Coarser sediments with a greater range of grain sizes should create a large number of potential niches (Gray 1974), and indeed this is the case for the present study where the highest diversities occurred in the site-groups with relatively complex sediment structure and greater sandy to coarse particle sizes. Nevertheless by far the greatest abundances, in contrast, occurred in the fine silt to muddy sites where large numbers of deposit feeders dominated.

Intermediate levels of disturbance from both abiotic fluctuations and predation have also been suggested as causes of increased diversity (Paine 1966; Menge & Sutherland 1976; Caswell 1978; Connell 1978; Stephenson & Sadacharan 1983) and as stabilising factors (Murdoch & Oaten 1975), by preventing monopolisation by competitively dominant species. This occurs through the continual opening of new patches which are then available to opportunistic invaders. This hypothesis also agrees with the present results. Site-Group VI (the 'Southern Shallows' of Stephenson *et al.* 1974), contains the highest species richness of all the site-groups. It is also relatively shallow compared to other sites, and thus more open to disturbance from storms and strong wave action. In fact seasonal shifts in sediment composition at these sites have already been noted by Stephenson *et al.* (1974) between March 1970

and December 1971. At that time that there was less fine sand and more mud at Stn 12; more very coarse and medium sand and less mud at Stns 13 and 14; and less coarse, medium and fine sand and more very fine sand and mud at Stn 15 (11–15). It seems reasonable to expect that such low level lability continues to operate in this area.

SEASONAL PATTERNS

As our study was undertaken over a single summer sampling period, we have no contemporary data on seasonality. Stephenson *et al.* (1974) conducted their study at eight sampling times over two years in an attempt to assess seasonal changes. Somewhat unexpectedly, they found interannual variability to be more important than seasonal variation, and their quarterly sampling program was inadequate with respect to understanding temporal changes. They suggested a ten-year sampling regimen would probably be necessary for patterns to emerge. Of great importance was the finding that different species-groups could separately characterise different seasons, and different years, as well as different sites. One set of species was replaced by another set (or sets) of species as time proceeded, and the species-year variance was almost double that of species-seasons, indicating that annual changes in species composition are more important than seasonal ones. Thus it is no real surprise that the present study also found species assemblages somewhat different from the 1974 study. It appears that it is the diversity and abundance of species present that indicates a healthy and productive system, rather than close conformity with previously defined communities that inevitably exhibit considerable spatial and temporal variability.

High rainfall with concurrent reduced salinity has been proposed as a major cause of faunal seasonality in a number of local studies including Park (1979) working on macrobenthos at the mouth of the Brisbane River, Vohra (1965) and Stejskal (1984) working on intertidal fauna at Victoria Point and Cribb Island respectively, and Young & Wadley (1979) studying epibenthic fauna in Moreton Bay. The Brisbane River has an average annual stream-flow of about 1.35 million megalitres (Cossins 1990), with very low flow periods interspersed with short mild to extreme flood events (Odd &

Baxter 1981). This is similarly true for the Logan-Albert River system that has a smaller catchment, but nevertheless has the most direct influence on our study area to the south of Peel Island.

Later studies by Stephenson (1980a, b, c) have indicated major recruitment to the Bay's benthic communities occurs in August/September with major depletion of benthic stocks in December, probably due at least in some areas, to increases in mobile predators and benthic-disturbors (fish and prawns) (Stephenson *et al.* 1978, 1982). Presumably species diversity would also show such seasonal fluctuations. The occurrence and abundance of rarer species would certainly be related to periods of high and low flux levels. Predictability of benthic species occurrence is a complex issue. Stephenson (1980c) found that while some species showed annual cycles, more species showed significant long-term cycles of between 2–7 years, with evidence of successional replacement of species groups. The scale of this type of species replacement is unknown — it is probably a relatively local phenomenon, but it is also possible that it could be of a more general nature relying on recruitment events from outside the Bay.

TROPHIC PATTERNS

The availability of food resources is influenced by the strength and patterns of bottom water movement and the settling rates of particulates. These may also be affected by the feeding habits and life-styles (active/sedentary, tubicolous/non-tubicolous, surface/subsurface etc.) of the individual species. The interaction of these factors helps determine the optimum environment, and thus the potential dominance patterns for each species (Word 1980). Our results have largely agreed with other studies in recording the numerical dominance of deposit feeders in muddy environments, and suspension feeding guilds in sandier substrates. We have also noted, perhaps a little more unusually, a rich and diverse predator/scavenger community in some site-groups. This may be a predator response to the numerical abundance of more sedentary suspension/deposit feeders, or perhaps a factor of the complexity of the bottom type providing a greater range of niches (e.g., presence of seagrasses and/or the establish-

ment of epibenthic communities based around the mussel, *Trichomya*). This aspect is worthy of more specific study and analysis.

One major element that our study did not address was the biomass of the faunal components. Biomass is a critical determinant of nutrient-cycling variables, yet reliable estimates of benthic faunal biomass are completely lacking for Moreton Bay. Wilson *et al.* (1993) estimated that, in Port Phillip Bay, suspension feeders (mostly bivalve molluscs) comprise half of the benthic macroinvertebrate biomass, and process a volume of water equivalent to the entire Bay in 16–17 days. Suspension feeders are estimated to be responsible for 15% of all organic matter ingested by benthic macroinvertebrates (including a significant fraction of planktonic primary production), but may account for over 40% of total assimilation of organic material. Deposit feeders (mostly crustaceans, echinoids and polychaete worms) make up about 35% of total macrobenthic biomass, and in a single year, are estimated to process a volume of sediment equivalent to the top 13 mm of Port Phillip Bay sediments. Estimates of nitrogen excretion from Port Phillip Bay benthic macroinvertebrates indicate that net annual secondary production by both benthic deposit- and suspension-feeding macroinvertebrates is about 62,700 tonnes C, equivalent to a Production/Biomass ratio of 2.81. The productivity of benthic organisms has so far been virtually ignored in Moreton Bay, and yet, given the unique geography and rich subtropical sediments, their contribution to net productivity may well exceed even the impressive figures estimated for Port Phillip Bay. Direct measurements of secondary production by benthic invertebrates are needed to firmly establish the important role of these organisms in the ecology of Moreton Bay.

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- APPENDIX 1**
Complete list of species.
- Phylum Porifera**
Class Calcarea
sponge 1
- Phylum Cnidaria**
Class Anthozoa
Order Actinaria
Cerianthidae
Cerianthus sp.
- Family not determined
unident anemone 1
unident anemone 2
unident anemone 3
unident anemone 4
- Phylum Nematoda**
nematode
- Phylum Nemertea**
nemertean orange band
nemertean pink
nemertean white
- Phylum Phoronida**
Phoronis australis Haswell, 1883
- Phylum Sipuncula**
Class Phascolosomatidea
Order Phascolosomatiformes
Phascolosomatidae
sipunculid 1
sipunculid 2
Class Sipunculidea
- Order Aspidosiphoniformes**
Aspidosiphonidae
Aspidosiphon sp.
- Order Golfingiiformes**
Golfingiidae
Golfingia trichocephala Sluiter, 1902
- Phascolionidae**
Phascolion sp.
- Themistidae**
Themiste sp.
- Phylum Annelida**
Class Polychaeta
Order Canalipalpata
Ampharetidae
ampharetid 2
ampharetid 3
Isolda pulchella Muller, 1858
Isolda sp. 1
- Chaetopteridae**
chaetopterid 1
- Cirratulidae**
cirratulid 1 (*Tharax* sp)
cirratulid 2,
cirratulid 3,
cirratulid 4,
- Flabelligeridae**
Coppingeria longisetosa Haswell, 1892
Diplocirrus sp
Pherusa sp. 1
Pherusa sp. 2
Piromis sp
- Magelonidae**
Magelona "cincta" Ehlers, 1908
Magelona "papillicornis" Muller, 1858
Magelona dakini Jones, 1978
- Oweniidae**
Owenia fusiformis Delle Chiaje, 1844
- Pectinariidae**
Pectinaria sp.
- Poecilochaetidae**
Poecilochaetus sp.
- Sabellariidae**
Idanthiysus sp.
- Sabellidae**
sabellid 1
sabellid 2

- sabellid 3
 sabellid 4
 sabellid 5
 Serpulidae
 serpulid 1
 serpulid 2
 serpulid 3
 Spionidae
Prionospio sp. 1
Prionospio sp. 2
Prionospio sp. 3
Pseudopolydora sp
Scolecopelides sp
 spionid 1
 spionid 2
 spionid 3
 spionid 4
 spionid 5
 spionid 6
 spionid 7
 spionid 8
 Sternaspidae
Sternaspis scutata (Renier, 1807)
 Terebellidae
Amacana trilobata (Sars, 1863)
Lanice conchilega (Pallas, 1766)
Loimia medusa (Savigny, 1818)
Lysilla pacifica Hesse, 1917
Pista pectinata Hutchings, 1977
Pista sp. 1
Pista trunca Hutchings, 1977
Pista typha Grube, 1878
Rhinothelopus lobatus Hutchings, 1974
Streblosoma gracile Caullery, 1944
Streblosoma sp
Terebella sp
 terebellid 1
 terebellid 2
 terebellid 3
 terebellid 4
 terebellid 5
 terebellid 6
Terebellides narribri Hutchings & Peart, 2000
Terebellides woolawa Hutchings & Peart, 2000
Thelepus sp
Order Palata
 Amphinomidae
Eurythoe sp.
Chloeia flava Pallas, 1766
 Chaetopteridae
Mesochaetopterus minutus Potts, 1914
 Chrysopetalidae
Blattwania sp.
 Chrysopetalidae
Palmyra sp.
 Dorvilleidae
Schiostomeringos filiformis Hutchings & Murray, 1984
 Eunicidae
Eunice vittata (Delle Chiaje, 1828)
Nematonereis unicornis (Grube, 1840)
Eunice australis Quatrefages, 1865
Lysidice sp
Marplysa sp
Eunice sp. 2
Eunice sp. 3
Eunice sp. 4
 Glyceridae
Glycera sp. 1
Glycera sp. 2
 Goniadidae
Goniada sp.
 Hesionidae
 hesionid 1
 hesionid 2
 Lacydoniidae
Paralacydonia paradoxa Fauvel, 1913
 Lumbrineridae
 lumbrinerid 1
 lumbrinerid 2
 lumbrinerid 3
 lumbrinerid 4
 lumbrinerid 6
 lumbrinerid 7
 lumbrinerid 8
 lumbrinerid 9
 lumbrinerid 10
 Nephtyidae
Nephtys australiensis Fauchald, 1965
Micronephthys spaerochaeta (Wesenberg-Lund, 1949)
 Nereididae
 nereid 1
 nereid 2
 nereid 3

nereid 4	syllid 7 (<i>Pharyngeovalvata</i> sp.)
nereid 5	syllid 8
nereid 6	syllid 9
nereid 7	syllid 10
nereid 8	syllid 11
nereid 9	syllid 12
Oenonidae	syllid 13
<i>Arabella</i> sp.	syllid 14
Onuphidae	Order Scolecida
<i>Diopatra</i> sp.	Capitellidae
<i>Onuphis</i> sp. 2.	capitellid 1
Phyllodocidae	capitellid 2
phyllodocid 1	capitellid 3
phyllodocid 2	capitellid 4
phyllodocid 3	capitellid 5
phyllodocid 4	capitellid 6
phyllodocid 5	Cossuridae
phyllodocid 6	<i>Cossura</i> sp.
phyllodocid 7	Maldanidae
phyllodocid 8	<i>Maldane</i> sp.
phyllodocid 9	maldanid 1
phyllodocid 10	maldanid 2
phyllodocid 12	maldanid 3
phyllodocid 13	maldanid 5
phyllodocid 14	maldanid 6
Polynoidae	maldanid 7
polynoid 1	maldanid 8
polynoid 2	maldanid 9
polynoid 3	maldanid 10
polynoid 4	maldanid 11
polynoid 5	Opheliidae
polynoid 6	<i>Armandia</i> sp. 1
polynoid 7	<i>Armandia</i> sp. 2
polynoid 8	<i>Ophelia</i> sp.
Sigalionidae	<i>Polyophthalmus pictus</i> (Dujardin, 1839)
sigalionid 1	Orbiniidae
sigalionid 2	<i>Haploscoloplos</i> sp.
sigalionid 3	orbiniid 1
sigalionid 4	orbiniid 2
sigalionid 5	<i>Phylo</i> sp.
Syllidae	Paraonidae
syllid 1 (<i>Opisthosyllis</i> sp.)	paraonid 1
syllid 2	paraonid 2
syllid 3	paraonid 3
syllid 4 (<i>Odontosyllis</i> sp.)	Scalibregmatidae
syllid 5 (<i>Syllis</i> sp.)	<i>Hyboscolex</i> sp.
syllid 6	<i>Scalibregma inflatum</i> Rathke, 1843

Polychaete Family not determined

unident sp. 1

unident sp. 2

Phylum Echinodermata

Class Echinoidea

Loveniidae

Echinocardium cordatum (Pennant, 1777)

Class Holothuroidea

Cucumariidae

Cucumariidae sp.

Holothuridae

Holothuria sp. 1

Holothuridae sp.

Synaptidae

Protankyra sp.

Class Ophiuroidea

Amphiuridae

Amphiuridae sp. 1

Amphiuridae sp. 2

Ophiocomidae

Ophiocomella sexradia (Duncan, 1887)

Ophiothrix sp. 1

Ophiotrichidae

Macrophiothrix sp. 1

Macrophiothrix sp. 2

Ophiotrichidae sp. 2

Ophiotrichidae sp. 3

Ophiuridae

Ophiura kinbergi Ljungman, 1866

Ophiuridae sp. 1

Ophiuridae sp. 2

Ophiuridae sp. 3

Phylum Mollusca

Class Bivalvia

Order Heterodonta

Cardiidae

Acrosterigma ? flava (Linnaeus, 1758)

Acrosterigma ? impolita

Fulvia sp.

Carditidae

Cardita precissii Menke, 1843

Chamidae

Chama asperclla Lamarck, 1819

Chama fibula Reeve, 1846

Chama limbula Lamarck, 1819

Chama pulchella Reeve, 1846

Chama ruderalis Lamarck, 1819

Corbulidae

Corbula ? crassa Reeve, 1843

Corbula ? monilis Hinds, 1843

Corbula morctonensis Lamprell & Healy, 1996

Corbula sp.

Corbula stephensoni Lamprell & Healy, 1996

Crassatellidae

Salaputium ? torresi (Smith, 1885)

Galeommatidae

Ambuscintilla sp.

Borniola ? lepida (Hedley, 1906)

Borniola ? radiata (Hedley, 1905)

Kellia ? rotunda (Deshayes, 1855)

Kellia sp.

Montacuta sp.

Scintilla sp. 1

Scintilla sp. 2

Scintilla sp. 3

Hiatellidae

Hiatella australis (Lamarck, 1819)

Laternulidae

Laternula attenuata Reeve, 1860

Lucinidae

Linga sperabilis (Hedley, 1909)

Mactridae

Meropesta nicobarica (Gmelin, 1791)

Mesodesmatidae

Paphies sp.

Pharidae

Ensiculus cultellus (Linnaeus, 1758)

Siliqua sp.

Psammobiidae

Gari livida (Lamarck, 1818)

Gari weinkauffi (Crosse, 1864)

Solenidae

Solen sp.

Solen vaginoides (Lamarck, 1818)

Tellinidae

Exotica donaciformis (Deshayes, 1854)

Tellina ? brazicri Sowerby, 1869

Tellina ? pinguis Hanley, 1844

Tellina ? tenuilirata Sowerby, 1867

Tellina gemonia (Iredale, 1936)

Tellina languida Smith, 1885

Tellina lilium Hanley, 1844

Tellina sp. 1

Tellina sp. 2

- Tellina* sp. 3
Tellina sp. 4
Tellina sp. 5
Tellina sp. 6
Tellina sp. 7 (orange rays)
Tellina sp. 8 (pink elongate)
- Ungulinidae**
Felaniella sp.
- Veneridae**
Antigona chemnitzii (Hanley, 1844)
Callista ? *roseotincta* (Smith, 1885)
Callista sp.
Circe ? *mistura* (Iredale, 1936)
Circe ? *plana* Ohdner, 1917
Circe scripta (Linnaeus, 1758)
Clementia papyracea (Gray, 1825)
Dosinia sculpta (Hanley, 1845)
Dosinia sp.
Marcia liantina (Lamarck, 1818)
Paphia ? *crassisulca* (Lamarck, 1818)
Paphia ? *exarata* (Phillipi, 1846)
Paphia gallus (Gmelin, 1791)
Paphia sp.
Paphia undulata (Born, 1780)
Pitar sp.
Placamen sidneyense (Menke, 1858)
Placamen tiara (Dillwyn, 1817)
Tapes ? *dorsatus* (Lamarck, 1818)
Tapes sp.
Venerupis anomala (Lamarck, 1818)
- Order Protobranchia**
- Nuculanidae**
Nuculana sp.
Yoldia ? *lata* (Hinds, 1843)
- Nuculidae**
Leionucula obliqua (Lamarck, 1819)
Leionucula sp.
- Solemyidae**
Solemya sp.
- Order Pteriomorpha**
- Anomiidae**
Patra australis (Gray, 1847)
- Arcidae**
Anadara trapezia (Deshayes, 1840)
Arca navicularis Brugui re, 1789
Barbatia foliata (Forssk I, 1775)
Trisidos tortuosa (Linnaeus, 1758)
- Glycymerididae**
Glycymeris radians (Lamarck, 1819)
Glycymeris striatularis (Lamarck, 1819)
- Malleidae**
Malleus albus Lamarck, 1819
Vulsella vulsella (Linnaeus, 1758)
- Mytilidae**
Modiolus ? *ostentatus* Iredale, 1939
Modiolus ? *peronianus* Laseron, 1956
Modiolus elongatus Swainson, 1821
Modiolus philippinarum Hanley, 1843
Modiolus sp.
Musculus albanus Laseron, 1956
Musculus chinensis Bernard, Cai & Morton, 1993
Musculus cumingianus Reeve, 1857, Mytilidae
Musculus nanus (Dunker, 1856)
Musculus sp.
Trichomya hirsuta (Lamarck, 1819)
- Ostreidae**
Dendrostrea sp.
Ostrea sp.
Saccostrea glomerata (Gould, 1850)
- Pectinidae**
Annachlamys sp.
Mimachlamys gloriosa (Reeve, 1853)
Mimachlamys sp.
Scaechlamys livida (Lamarck, 1819)
- Pinnidae**
Pinna ? *bicolor* Gmelin, 1791
Pinna muricata Linnaeus, 1758
- Plicatulidae**
Plicatula australis Lamarck, 1819
- Pteriidae**
Pinctada albina (Lamarck, 1819)
Pinctada maculata (Gould, 1850)
- Class Gastropoda**
- Order Caenogastropoda**
- Buccinidae**
Cantharus sp.
- Columbellidae**
Anachis atkinsoni Tenison Woods, 1875
Anarchis ? *troglodytes* (Souverbie, 1866)
Anarchis marquesa (Gaskoin, 1852)
Anarchis miser (Sowerby, 1844)
Anarchis smithii (Angas, 1877)
Anarchis sp.
Mitrella ? *dictua* (Tenison Woods, 1878)

- Mitrella* sp.
Pyrene ? *testudinaria* (Link, 1807)
Zafra darwini Angas, 1877
- Epitoniiidae
Epitonium sp.1
Epitonium sp.2
Epitonium sp.3
Epitonium sp.4
Epitonium tacitum (Iredale, 1936)
- Eulimidae
Eulina sp.
Hypermastus cf *mucronata* (Sowerby, 1866)
Mucronalia sp.
Pictobalcis sp.
- Fascioliariidae
Latirus sp.
- Muricidae
Latiaxena ficula (Reeve, 1848)
- Nassariidae
Nassarius heavy sculpture
Nassarius pauperus (Gould, 1850)
Nassarius sp.
- Naticidae
Natica ? *alapapilionis* (Röding, 1798)
Natica ? *vitellus* (Linnaeus, 1758)
Natica sp.
Natica subcostata (Tenison Woods, 1878)
Polinices ? *powisiana* (Récluz, 1844)
Polinices conicus (Lamarck, 1822)
- Rissoidae
Estea sp.
- Rissoinidae
Fictonoba sp.
- Terebridae
Terenolla pygmaea (Hinds, 1844)
- Triphoridae
Cauter similis (Pease, 1871)
- Turridae
 White turrid
- Vitrinellidae
Pseudoliotia cf *speciosa* (Angas, 1877)
Sigaretorinus planus (A. Adams, 1850)
- Order Cephalaspidea**
- Philinidae
Philine sp.
- Order Heterobranchia**
- Acteonidae
- Pupa* sp.
- Amathinidae
Amathina tricarinata (Linnaeus, 1767)
- Pyramidellidae
Pyramidellid sp. 1 ('*Elodiamea*' sp.)
Pyramidellid sp. 2 ('*Linopyrga*' sp.)
Pyramidellid sp. 3 ('*Miralda*' sp.)
Pyramidellid sp. 4 ('*Syrnola*' sp.)
Pyramidellid sp. 5 ('*Turbonilla*' sp.)
Pyramidellid sp. 6
Pyramidellid sp. 7 (spiral ribs, tall)
- Retusidae
Retusa sp. 1
Retusa sp. 2 (tall spire)
Rhizorus sp.
Tornatina sp.
- Ringiculidae
Ringicula sp.
- Rissoellidae
Rissoella sp.
- Scaphandridae
Atys sp.
Cylichna sp. 1
Cylichna sp. 2
Cylichna sp. 3
- Order Neritimorpha**
- Neritinae
Theodoxus ? *oualaniensis* (Lesson, 1831)
- Order Vetigastropoda**
- Fissurellidae
 ? *Puncturella* sp.
Diodora jukesii (Reeve, 1850)
Scutus unguis (Linnaeus, 1758)
- Phasianellidae
Tricolia ? *fordiana* (Pilsbry, 1888)
- Trochidae
Calthalotia indistincta (Wood, 1828)
Herpetopoma atrata (Gmelin, 1791)
- Order Polyplacophora**
 Chitons (unidentified)
- Order Scaphopoda**
- Order Dentaliida**
- Dentaliidae
Dentalium ? *cheverti* Sharp & Pilsbry, 1897
Dentalium ? *octangulatum* Donovan, 1803
Dentalium goftoni Lamprell & Healy, 1998
Dentalium robustum Brazier, 1877

Laevidentaliidae

Laevidentalium ? *longitrorsum* (Reeve, 1842)

Order Gadilida

Pulsellidae

Compressidens platyceras (Sharp & Pilsbry, 1897)

Pulsellum eboracense (Watson, 1879)

Phylum Arthropoda

Class Pycnogonida

Order Pantopoda

Ammonotheidae

Achelua assimilis (Haswell, 1885)

Ascorhynchus longicollis

Nymphonidae

Nymphon boogoora

Nymphon mollerii

Phoxichilidiidae

Anoplodactylus cribellatus

Anoplodactylus tubiferus

Subphylum Crustacea

Class Ostracoda

Chelicopia pertinax Kornicker, 1994

Cycloleberis sp. 1

Eusarsiella fallomagna Kornicker, 1994

Eusarsiella sp. 1

Eusarsiella sp. 2

Eusarsiella sp. 3

Ostracod sp. 1

Ostracod sp. 2

Ostracod sp. 3

Ostracod sp. 4

Ostracod sp. 5

Ostracod sp. 6

Ostracod sp. 7

Ostracod sp. 8

Pleoschisma mindax Kornicker, 1994

Class Malacostraca

Order Leptostraca

Nebaliidae

Nebalia sp.

Paranebaliidae

Paraebalia levinebalia Walker-Smith, 2001

Paranebalia sp.

Order Amphipoda

Ampeliscidae

Ampelisca sp.

Byblis sp. 1

Byblis sp. 3

Aoridae

aorid Unident sp.

Caprellidae

caprellid 1

caprellid 2

caprellid 3

caprellid 5

Corophiidae

Cheiriphotis sp. 1

Cheiriphotis sp. 2

Cheiriphotis sp. 3

Cheiriphotis sp. 4

corophid 1

Paraoroides sp. 1

Paraoroides sp. 3

Paraoroides sp. 4

Siphonocetes sp.

Isaeidae

Ampelisciphotis sp. 1

Ampelisciphotis sp. 2

Gauniaropsis sp.

Leucothoidae

Leucothoe assimilis Barnard, 1974

Liljeborgiidae

liljeborgid 1

liljeborgid 2

Lysianassidae

lysianassid 1

Oedicerotidae

oedicerotid 1

oedicerotid 2

oedicerotid 3

Phliantidae

Phliantis sp.

Phoxocephalidae

Birubius cf *wirakus* Barnard & Drummond, 1978

Birubius sp. 1

Birubius sp. 2

Birubius sp. 3

Birubius sp. 4

Platyschnopidae

Platyschnopus mirabilis Stebbing, 1888

Amphipod family not determined

amphipod 01

amphipod 02

amphipod 03

amphipod 04

- amphipod 05
- amphipod 06
- amphipod 08
- amphipod 09
- amphipod 10
- amphipod 11
- amphipod 12
- amphipod 13
- amphipod 14
- amphipod 15
- Order Cumacea**
- Bodotriidae**
- Bodotriid sp.
- Cyclaspis ornosculpta* Tafe & Greenwood, 1996
- Cyclaspis* sp. 1
- Cyclaspis* sp. 3
- Cyclaspis* sp. 4
- Diastylidae**
- Diastylid sp.
- Gynodiastylis* sp. 1
- Gynodiastylis* sp. 2
- Lampropidae**
- Lampropidae sp.
- Leuconidae**
- Leptostylis* sp. 1
- Nannastacidae**
- Nannastacidae sp.
- Order Isopoda**
- Aegidae**
- Aegidae sp. 1
- Antarcturidae**
- Antarcturidae sp. 1^a
- Anthuridae**
- Amakusanthura* sp. 1
- Amakusanthura* sp. 2
- Arcturidae**
- Neastacilla* sp. 1
- Neastacilla* sp. 2
- Neastacilla* sp. 3
- Neastacilla* sp. 4
- Neastacilla* sp. 5
- Austrarcturellidae**
- Austrarcturella* sp. 1
- Bopyridae**
- Anuropodione australiensis* Bourdon, 1976 (in *Pisidia dispar*)
- Cirolanidae**
- cirolanid 1
- Cirolanidae** sp. 1
- Natatolana* sp. 1
- Gnathidae**
- Gnathia* sp.
- gnathid sp
- Gnathidae** sp. 1
- Leptanthuridae**
- Ullakanthura namoo* Poore, 1978
- Paranthuridae**
- Paranthura* sp. 1
- Pseudidotheidae**
- Pseudidothea* sp. 1
- Serolidae**
- Serolina holia* Poore, 1987
- Serolina* sp
- Sphaeromatidae**
- Sphaeromatid sp. 1
- Sphaeromatid sp. 2
- Sphaeromatid sp. 3
- Sphaeromatid sp. 4
- Sphaeromatid sp. 5
- Sphaeromatid sp. 6
- Sphaeromatid sp. 7
- Sphaeromatid sp. 8
- Sphaeromatid sp. 9
- Order Tanaidacea**
- Anarthruridae**
- Tanaopsis canaipa* Bamber, 2008
- Apseudidae**
- Bunakenia anomala* Guṇu, 2006
- Kalliapseudidae**
- Transkalliapseudes banana* Bamber, 2008
- Leptocheliidae**
- Konarus cheiris* Bamber, 2006
- Leptochelia opteros* Bamber, 2008
- Pseudoleptochelia fairgo* Bamber, 2005
- Parapseudidae**
- Pakistanapseudes australianus* Guṇu, 2006
- Paratanaididae**
- Bathytanais culteriformis* Larsen & Heard, 2001
- Typhlotanaididae**
- Antiplotanais coochimudlo* Bamber, 2008
- Whiteleggiidae**
- Whiteleggia stephensoni* Boesch, 1973
- Order Mysidacea**
- Mysidae**

- Gastrosaccus queenslandensis* Bacescu & Udrescu, 1982
Mysid sp. 1
Mysid sp. 2
Mysid sp. 4
Mysid sp. 5
Mysid sp. 6
Mysid sp. 7
Mysid sp. 8
Mysid sp. 9
Mysid sp. 10
Order Decapoda
Alpheidae
Alpheus edwardsii (Audouin, 1826)
Alpheus sp. 2
Alpheus sp. 3
Alpheus sp. 4
Callinassidae
Callinassa australiensis Dana, 1852
Callinassa sp.
Crangonidae
Pontopluteus angustirostris De Man, 1918
Dorippidae
Paradorippe australiensis (Miers, 1884)
Hippolytidae
Lysmata sp.
Leucosiidae
Leucosia sp. 1
Nursia sinuata Miers, 1877
Nursia nr *sinuata* sp. 2
Nursia nr *sinuata* sp. 3
Philyra sp. 1
Majidae
Achaeus sp. 1
Achaeus sp. 2
Hyastenus sp. 1
Pilumnidae
Cryptolutea sp. 1
Heteropilumnus fimbriatus (H. Milne Edwards, 1834)
Heteropilumnus sp. 2
Pilumnus sp. 2
Rhizopinae sp. 1
Pinnotheridae
Pinnotheres sp. 1:
Porcellanidae
Pisidia dispar
Polyonyx sp. 1
Portunidae
Thalamita sp. 1
Thalamita sp. 2
Processidae
Processa dimorpha Hayashi, 1975
Processa sulcata Hayashi, 1975
Xanthidae
Actaea sp. 1
Xanthid sp. 1
Xanthid sp. 2
Phylum Hemichordata
Class Enteropneusta
Ptychoderidae
Glossobalanus hedleyi (Hill, 1897)
Chordata
Cephalochordata
Leptocardii
Branchiostomidae
Branchiostoma moretonensis Kelly, 1966